Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Flood Plan Coordination Organisation

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

NEMREP

NORTHEAST REGION ENVIRONMENT MANAGEMENT, RESEARCH, AND EDUCATION PROJECT

PRE-FEASIBILITY STUDY
FINAL REPORT
December 1994

Shawinigan Lavalin (1991) Inc.
Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services
Institute For Development Education and Action
Nature Conservation Movement

Canadian International Development Agency

COVER PHOTO: A typical village in the deeply flooded area of the Northeast Region. The earthen village platform is constructed to keep the houses above water during the flood season which lasts for five to seven months of the year. The platform is threatened by erosion from wave action; bamboo fencing is used as bank protection but often proves ineffective. The single *hijal* tree in front of the village is a remnant of the past lowland forest that used to cover much of the region. The houses on the platform are squeezed together leaving no space for courtyards, gardens or livestock. Water surrounding the platform is used as a source of drinking water and for waste disposal from the hanging latrines. Life in these crowded villages can become very stressful especially for the women, because of the isolation during the flood season. The only form of transport from the village is by small country boats seen in the picture. The Northeast Regional Water Management Plan aims to improve the quality of life for these people.

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Acronyms and Abbreviations

ADB	Asian Development Bank
ADAB	Association of Development Agencies in Bangladesh
ADT	air-dried tonne
AWB	Asian Wetland Bureau
BCIC	Bangladesh Chemical Industries Corporation
BCS	Bangladesh Chemical Society
BOD	biological oxygen demand
BRAC	Bangladesh Rural Advancement Committee
CIDA	Canadian International Development Agency
CITES	Convention on Trade in Endangered Species
COD	chemical oxygen demand
DC	District Commissioner
DEPC	Department of Environment Pollution Control
DOE	Department of Environment
DPHE	Department of Public Health Engineering
EIA	Environmental impact assessment
EMP	environment management plan
EPAM	Environmental planning, assessment, and management
FAO	Food and Agriculture Organization
FAP	Flood Action Plan
FCDI	flood control, drainage, irrigation
FFYP	Fourth Five Year Plan
FMP	Forestry Master Plan
GDP	gross domestic product
GEF	Global Environment Fund
GIS	geographical information system
GTZ	German Technical Assistance
HYV	high yielding variety
ICDP	integrated conservation and development project
ICF	International Conservation Foundation
IEE	initial environmental examination
IUCN	International Union for the Conservation of Nature
IWC	International Waterfowl Census
IWRB	International Waterfowl and Wetland Bureau
MAB	Man and the Biosphere Programme
MOEF	Ministry of Environment and Forests
MOL	Ministry of Land
NACOM	Nature Conservation Movement
NCS	National Conservation Strategy
NEMAP	National Environment Management Action Plan
NEMREC	Northeast Region Environment Management, Research, and Education Centre
NEMREP	Northeast Region Environment Management, Research, and Education Project
NERP	Northeast Regional Water Management Plan Project (FAP 6)
NGO	Non-governmental organization

ODA	Overseas Development Assistance (UK)
RDB	Red Data Book (IUCN, 1990a)
SAARC	South Asia Association for Regional Cooperation
SLI/NHC	Shawinigan-Lavalin/Northwest Hydraulic Consultants
SPPM	Sylhet Pulp and Paper Mill
SSC	Species Survival Commission
TDS	total dissolved solids
UNCED	United Nations Council on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WTMC	Wildlife Trade Monitoring Centre
WWF	World Wide Fund for Nature (formerly World Wildlife Fund)

NERP DOCUMENTS

The Northeast Regional Water Management Plan is comprised of various documents prepared by the NERP study team including specialist studies, the outcome of a series of public seminars held in the region, and prefeasibility studies of the various initiatives. A complete set of the Northeast Regional Water Management Plan Documents consists of the following:

Northeast Regional Water Management Plan

Main Report
Appendix: Initial Environmental Evaluation

Specialist Studies

Participatory Development and the Role of NGOs
Population Characteristics and the State of Human Development
Fisheries Specialist Study
Wetland Resources Specialist Study
Agriculture in the Northeast Region
Ground Water Resources of the Northeast Region
Surface Water Resources of the Northeast Region
Regional Water Resources Development Status
River Sedimentation and Morphology
Study on Urbanization in the Northeast Region
Local Initiatives and People's Participation in the Management of Water Resources
Water Transport Study

Public Participation Documentation

Proceedings of the Moulvibazar Seminar
Proceedings of the Sylhet Seminar
Proceedings of the Sunamganj Seminar
Proceedings of the Sherpur Seminar
Proceedings of the Kishorganj Seminar
Proceedings of the Narsingdi Seminar
Proceedings of the Habiganj Seminar
Proceedings of the Netrokona Seminar
Proceedings of the Sylhet Fisheries Seminar

Pre-feasibility Studies

Jadukata/Rakti River Improvement Project
Baulai Dredging
Mrigi River Drainage Improvement Project
Kushiyara Dredging
Fisheries Management Programme
Fisheries Engineering Measures
Habiganj-Khowai Area Development
Development of Rural Settlements
Pond Aquaculture
Applied Research for Improved Farming Systems
Manu River Improvement Project
Narayanganj-Narsingdi Project
Narsingdi District Development Project
Northeast Region Environment Management, Research, and Education Project (NEMREP)
Upper Kangsha River Basin Development
Upper Surma-Kushiyara Project
Surma Right Bank Project
Surma-Kushiyara-Baulai Basin Project
Kushiyara-Bijna Inter-Basin Development Project
Dharmapasha-Rui Beel Project
Updakhali River Project
Sarigoyain-Piyain Basin Development

Glossary of Terms

ENGLISH TERMS

Biodiversity — Variability among living organisms from all sources including *inter alia* terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; diversity within species, between species and of ecosystems (Convention on Biodiversity, 1992).

Ecosystem — Dynamic complex in which plant, animal and microorganism communities and their non-living environment interact as a functional unit (Convention on Biodiversity, 1992).

Lowland — Used here to refer to land elevations at and below the homestead level.

Upland — Used here to refer to land elevations above and not including the homestead level.

Wildlife — Most generally, organisms living in a natural state. The legal definition in Bangladesh restricts it to vertebrate species, other than humans, fish, and usually domesticated animal species, and including the eggs of birds and reptiles (Bangladesh Wildlife (Preservation) (Amendment) Act 1974).

Wetland — An area of land saturated with or submerged under water. Legal definitions vary from country to country. The term is not defined in any domestic legislation in Bangladesh. Rec. C.4.7 of the Conference of the Contracting Parties to the Ramsar Convention identifies 36 broad types, 26 of which are natural or semi-natural and ten man-made.

Wetland values — All valued products and services derived from wetlands, such as food, fodder, fuel, medicines, flood storage, water purification, and so on.

BANGLA TERMS

boro — Rice grown in the winter dry season.
beel — Permanent shallow lake.
haor — River back swamp.
jheel — Abandoned river course.
kanda — Ridges that are higher than the haor basin but lower than homestead land.
katha — Branches or bamboo piles place in the water to provide shelter for fish.
khas — Government-owned land.
khal — Small drainage channel.
kobiras — Practitioner of traditional medicine.

Table of Contents

1. INTRODUCTION

1.1 PROJECT ORIGINS AND HISTORY

The Northeast Region Environment Management, Research, and Education Project (NEMREP) is composed of eleven initiatives proposed in September 1993 in the Regional Water Management Plan produced by the Northeast Regional Water Management Plan Project (NERP), Item 6 of the Bangladesh Flood Action Plan (FAP). A map of the region is shown in Figure 1.

The NEMREP initiatives consist of those NERP initiatives which fall within the institutional mandate of the Ministry of Environment and Forests. They address strategic issues in biodiversity and surface quality management, including institutional issues in these two areas. The biodiversity initiatives include restoration and improved management of key habitats, reflecting the close relationship between biodiversity and forestry.

The eleven initiatives are:

- Biodiversity initiatives

  — *Locally Based Management of Internationally Significant Wetland Sites*
  — *Threatened Ecological Community Recovery*
  — *Threatened and Commercially Threatened Species Recovery*
  — *Upland Biodiversity Conservation Studies and Implementation*

- Surface water quality management initiatives

  — *Regional Water Quality Characterization*
  — *Pulp and Paper Mill Effluent Treatment*
  — *Industrial Pollution Abatement at Smaller Industrial Facilities*
  — *Duckweed-Based Domestic Wastewater Treatment*

- Institutional development initiatives

  — *MOEF/DPHE Strategic Planning Exercise: Surface Water Quality Management*
  — *MOEF Strategic Planning Exercise: Biodiversity Conservation*
  — *Northeast Region Environment Management, Research, and Education Centre (NEMREC)*

The portfolio of initiatives proposed by NERP were conceptualized and selected within the context of a regional strategic planning exercise focusing on water system development within the context of regional development. NERP planning proceeded as follows:

- Characterize present conditions in the Northeast Region through specialist studies of water resources, development, hydrology, river sedimentation and morphology, agriculture, fisheries, wetland resources, human resources development, and institutions (see NERP Report List, pp. ii and iii).

- Analyze international, national, and regional/local driving forces; regional development issues and strengths, weaknesses, opportunities, and threats; and the future without-Plan scenario. Each of these areas addressed the development system as a whole and the water system in particular, with the latter defined to include biological and other systems particularly dependent upon in-stream and floodplain water (fisheries, wetlands, navigation, etc.), in addition to the water resources themselves and measures to manage them (flood control, drainage, irrigation, and sediment management).

- Articulate a strategic plan for regional water management in terms of a set of strategic thrusts focusing on key system elements, based on information generated in the foregoing steps.

- Conceptualize initiatives addressing strategic thrusts. Note that strategising and project conceptualization are not sequential but rather complementary and parallel.

The NEMREP initiatives relate to the strategic thrusts focused on biodiversity enhancement and sustainable management; urban protection and environmental improvement; integrated development of deeply flooded areas; and institutional development.

1.2 STUDY PREPARATION

This pre-feasibility study was prepared over a period of several months in mid-1993, based on work of the NERP biodiversity and surface water quality management team during NERP Phase I (August 1991 to October 1993). The team was composed of an environment management specialist from SLI/NHC; wildlife biologists, ornithologists, and botanists from the non-governmental organization (NGO) Nature Conservation Movement (NACOM); an ornithologist/wetland specialist from the international NGO Asian Wetland Bureau; and a water quality/water treatment specialist from SLI/NHC.

The team's biodiversity findings so far, including data from the 1992/3 field season in the lowlands of the region, are presented in the draft final *Wetland Resources Specialist Study* (NERP, 1993). The surface water quality management investigation, which was much less extensive, is documented in internal NERP reports and memoranda.

Supporting inputs were provided by many of the other NERP team members, in particular by the economist, the community organizer/sociologist from the NGO IDEA, the socioeconomist, and the Fisheries Team.

1.3 REPORT STRUCTURE

The report is organized as follows:

- Chapter 2, *Background and Rationale*, presents the policy context for the project; a brief description of the region; an overview of relevant institutional background; and the rationale for each element of the project, including a characterization of the future-without-project scenario.

- Chapter 3, *Project Overview*, briefly describes the goal and objectives of the project; its structure; costs; and phasing.

- Chapter 4, *Organization and Management*, presents the organizational and management structure of the project.

- Chapter 5, *Impacts and Multi-Criteria Analysis*, summarizes the expected impacts of the project; discusses financial, economic, and sustainability considerations; and presents the multi-criteria analysis of the project as required for project studies prepared under the Flood Action Plan.

- Chapter 6, *Detailed Description of Work Packages*, presents information on each element of the project.

- Annex A presents the figures.

- Annex B presents lists of bird, mammal, reptile, amphibian, and macrophyte species. These lists include all species known or thought to have occurred in the lowlands (homestead level and below) of the region, plus some upland (mainly bird) species.

- Annex C presents excerpts from *Duckweed Aquaculture* (Skillicorn *et al.*, 1993) and Natural Systems for Waste Management and Treatment by Sherwood C. Reed, E. Joe Middlebreaks and Ronald W. Crites (McGraw Hill, 1988).

- Annex D presents the initial environmental evaluation of the project, as required for project studies prepared under the Flood Action Plan.

2. BACKGROUND AND RATIONALE

2.1 POLICY CONTEXT

The Government of Bangladesh has clearly committed itself to:

- Environmentally sound management in general,
- Environmentally sound management of biodiversity assets, including ecologically valuable areas such as wetlands and particular communities and species, and
- Efforts to achieve and maintain environmental quality, including air and water quality, which is acceptable to domestic, industrial, and agricultural users, and which support sustainable ecosystem functioning, including fisheries production

International agreements and national policies relevant to NEMREP are catalogued in Table 2.1 and described below.

2.1.1 National and sectoral policy statements

Memorandum for the Bangladesh Aid Group 1992-93. This document summarizes the 'New Development Perspective', the Government's "vision for the future development of the country consistent with participatory democracy." Overall goals are identified, and among nine strategies specified to meet these goals is:

> "ix. integration of national conservation strategy to prevent the degradation of the environment and improve its capacity of sustainable development with multi-level economic planning." - p. 2

Eight 'selected development issues' are identified and discussed in the document. One of these is "Environmental Protection and Management"; part of the discussion of it reads,

> "For protection and conservation of natural resources and to link all developmental activities with the environment for ensuring sustainable development, the following objectives will be pursued during the FFYP period -
>
> "(a) control and prevention of environmental pollution and degradation related to soil, water, and air;
>
> "(b) promotion of environment friendly activities in the field of development;
>
> "(c) preservation, protection, and development of natural resource bases;
>
> "(d) strengthening the capabilities of public and private sectors to manage environment concern as a basic requisite for sustainable development; and
>
> "(e) creation of people's awareness for participation in environment protection activities.

Table 2.1: International Agreements and National Policies Affecting Wetlands

POLICY DOCUMENT	STATUS & DATE
Memorandum for the Bangladesh Aid Group 1992-93	April 1992.
Fourth Five Year Plan 1990-5	Revised Draft, March 1991.
National Environment Policy	Approved April 1992.
National Conservation Strategy (NCS)	Reviewed by concerned Ministries. Submission to Cabinet imminent.
National Environment Management Action Plan (NEMAP)	In preparation.
Forestry Master Plan	In preparation.

INTERNATIONAL AGREEMENT	STATUS & DATE
Ramsar Convention on Wetlands of Importance Especially as Waterfowl Habitat	Ratified 30 April 1992. Sundarban declared as country's first Ramsar site
Convention on International Trade in Endangered Species (CITES)	Ratified 20 Nov 1991.
Rio Convention on Biological Diversity	Signed June 1992. MOEF is preparing instrument of accession.
World Heritage Convention	Accepted as member 3 August 1983. Instrument of accession deposited 1983. Ratification incomplete. Two cultural heritage sites have been inscribed in the World Heritage list. [but see CIDA, 1989, p. 20; 'signatory 1987, part of Sundarban East sanctuary declared']
UNESCO Man and the Biosphere Programme	Accepted as member. National Committee exists.

"For attainment of the above objectives, the Ministry of Environment and Forest has already initiated a number of actions in different areas. . . . draft national environmental policy . . . draft National Conservation Strategy . . . provision for reflecting Environmental Impact Assessment (EIA) in all public sector projects. Similar measure is underway for the private sector projects. The Pollution Control Office set up in 1977 has been thoroughly reorganised, expanded and elevated as the Department of Environment. The existing Environmental Legislation is being revised in order to re-orient it to the requirement of the present time. . . . [MOEF] has also prepared a draft National Environment Management Action Plan (NEMAP) to address major environmental issues and concerns . . . Environmentally

vulnerable areas have been identified for priority action taking into consideration the developmental needs." - p. 76.

National Environment Policy. This is the Government's most comprehensive statement of overall environmental policy. It consists of an introductory statement; six objectives; policies in each of 15 sectoral and issue areas; and a short section on institutional arrangements. Points of particular relevance are (page numbers refer to the English translation in typescript):

Objectives:

"Maintenance of the ecological balance and over all progress and development of the country through protection and improvement of the environment. . ." - p. 2

"Ensuring sustainable, long-term, and environmentally congenial utilisation of all national resources" - p. 2

Policies:

"Conserve and develop wetlands and protect migratory birds. . . ." [(6), Forest, Wildlife, and Bio-diversity] - p. 4

"Prevent activities which diminish the wetlands/natural habitats of fish and encourage promotional measures in this regard. . . ." [(2), Fisheries and Livestock] - p. 4

"Ratify all environment-related International Laws/Conventions/Protocols that Bangladesh considers ratifiable and amend/modify existing laws/regulations in line with the ratified laws/conventions/protocols." [(4), Legal Framework] - p. 7

Institutional arrangements

"MOEF would coordinate the implementation of this policy. A National Environment Committee with the Head of Government as the Chairperson be constituted to give overall direction for implementation of the environment policy." - p. 7

Fourth Five Year Plan 1990-5. "Since Bangladesh is a small country with very large population, extra care is required to ensure that economic development does not lead to increased deterioration of its ecology and environment." (From Chapter I, Framework for the Perspective Plan, p. I.3.)

The Plan does not, however, dedicate a chapter or section to environmental concerns as such. These are dealt with sectorally; some of the relevant aspects are noted below.

In agriculture (Chapter V, Section B), flood-prone wetland areas are recognized as marginal for agriculture, and expansion or improvement of cropping in these areas is not sought:

"Floods are a fact of life and a part of the ecosystems of Bangladesh affecting land use pattern and the agricultural system of the country. While effective flood protection measures will form an integral part of development efforts during the Fourth Plan period, production plans in the crop sub-sector would focus attention on low-risk areas with less reliance on summer crops particularly in flood-prone areas." - p.V.A-13

DK

In flood control and water resources (Chapter V, Section B), the need for integrated planning, which could include consideration of wetland values, is noted:

> "The FFYP would focus attention on these aspects [agriculture, fishery, land use, and other environmental and socioeconomic considerations] in planning and implementation of future . . . programmes through integrated planning by involving all concerned agencies of the Government as well as the local people." - p. V.B-10

In fisheries (Chapter V, Section C):

> "Protection and conservation measures will include: . . . imposition of penalty on the industrial dumping of untreated and harmful industrial wastes into any open water system." -p. V.C-5

In forestry (Chapter V, Section E),

> "To preserve the national heritage, a network of protected areas characterising different types of terrestrial life and ecosystems will be established to help maintain biodiversity, and preserve gene pools and critical habitats of rare and endemic plants and animals. The national botanical gardens will be further developed. Measures will be taken to preserve and protect the national parks system in its existing form. Particular emphasis will be given to wildlife protection and preservation through strict enforcement of existing laws and establishment of game sanctuaries." - p. V.E-11

National Conservation Strategy. The NCS is "the blueprint for the integration of both environmental and economic concerns" (p. i). It has been reviewed by the relevant ministries and its submission for Cabinet approval is thought to be imminent. It states that:

> "A national policy should be formulated for preservation of wildlife. The proposed policy will include an objective statement specifying areas protected for preservation and regeneration of wildlife . . . [It] should be linked with the national forest policy to avoid conflict." (p. 119).

It also says that

> "The Protected Areas System of National Parks, Wildlife Sanctuaries, and Game Reserves should be expanded and maintained since they are the areas of unique richness in biodiversity." (p. 155)

National Environment Management Action Plan. Currently, a set of sectoral discussion papers prepared by the NEMAP consultants are being circulated to Government for review. Each paper identifies sectoral policy, key environmental issues, intersectoral linkages, relevant GOB environmental policy, an environmental action plan (long list of desirable actions), and key areas of intervention (short list). NERP has been able to obtain copies of papers covering the areas of agriculture, fisheries, water resources, forestry, and coastal and marine resources management.

Forestry Master Plan. The Forestry Master Plan (FMP) Project concluded earlier in 1993. It produced a plan for the forestry sector and supporting reports. The Plan is under review by the Government.

2.1.2 International agreements

Rio Convention on Biological Diversity. This instrument was adopted and signed by 157 nations including Bangladesh (and Canada) at the United Nations Conference on Environment and Development (UNCED) on 14 June 1992 at Rio de Janeiro, Brazil. MOEF is preparing the instrument of accession. The Convention "establishes new legal commitments on conservation, finance, access, technology transfer and benefit sharing that are likely to make it an extremely important instrument for the conservation of biological diversity in the years ahead. It has both conservation and development objectives and there is a strong link between the needs of people and conservation." Among other things, the Convention requires Contracting Parties (quotes taken from Biodiversity Coalition, 1992):

- "to develop national strategies, plans, and programmes to conserve and use sustainably biological diversity . . .
- "[to] integrat[e] . . . conservation and sustainable use of biological diversity into sectoral and cross-sectoral plans and policies . . .
- "to identify components of biological diversity important for conservation and sustainable use; to identify threats to them; and to monitor them . . .
- "[to] establish[] 'a system of protected areas or areas where special measures need to be taken';
- "[to] regulat[e] (private) or [to] manag[e] (public) biological resources important for biodiversity conservation to ensure their conservation and sustainable use . . .
- "[to] rehabilitat[e] degraded ecosystems and promot[e] recovery of threatened species . . .
- "to legislat[e] for protection of threatened species;
- "[to] prevent[] introduction of exotic species;
- "[to] encourag[e] and maintain[] relevant practices of indigenous and local communities;
- "[to] support *ex situ* conservation 'predominantly for the purpose of complementing *in situ* measures' and to support setting up facilities in countries of origin, especially countries of origin, and to help recovery and re-introduction of threatened species . . .
- "to adopt 'measures that act as incentives for the conservation and sustainable use of components of biological diversity' . . .
- "to develop research and training capabilities especially in developing countries . . .[and] to conduct public education and awareness programs . . .

20

- "to adopt EIA procedures for projects 'likely to have significant adverse effects on biological diversity with a view to avoiding or minimising such effects.' . . .

- "to facilitate access to genetic resources for environmentally sound uses, although access must be 'on mutually agreed terms' and 'subject to prior informed consent' . . . parties are encouraged to conduct their research on genetic resources in the country of origin and should share benefits . . . with the Party providing the resources . . .

- "to provide or facilitate access to technologies relevant to the conservation and sustainable use of biological diversity; and technologies that make use of genetic resources and do not significantly damage the environment . . .

Additional articles of the Convention encourage Parties to facilitate information exchange and technical and scientific cooperation to help developing states to strengthen their human skills and institutions; and provides for developing countries to participate in and have priority access to the results of biotechnology research. Each Party "undertakes to provide financial support ' in accordance with its capabilities' for national measures to achieve the Convention's objective. Developed country Parties 'shall provide new and additional financial resources to enable developing country Parties to meet the agreed full incremental costs' of implementing the Convention."

Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat. The Ramsar Convention is an inter-governmental treaty which provides the framework for international cooperation for the conservation of wetland habitats. Wetlands are recognized as being of international importance because local human impacts such as exploitation and pollution can affect wetlands in other countries; many wetland animals migrate through several countries; and many countries required advice and support from others in order to conserve their own wetlands. The Contracting Parties to the Convention (Switzerland Fed. Off. Environ. For. Landscape, undated):

- Accept the obligation to include wetland conservation within their national land-use planning;

- Have to promote the wise use of wetlands in their territory and maintain the ecological character of these wetlands (characteristics such as quality of soil, water, plants, and animals);

- Must establish nature reserves in areas of special ecological value;

- Undertake to train personnel in wetland research, management, and wardening;

- Designate the world's most significant sites for inclusion in a "List of Wetlands of International Importance"; and

- Undertake to cooperate for the management of shared water systems and the conservation of shared migratory species.

The Convention is the only inter-governmental agreement to deal with wetland conservation. It was drawn up in 1971 at an international meeting in Ramsar, Iran, and entered into force in 1975. More than 55 countries are party to the Convention; 11 are in Asia (Iran, Pakistan, Russia, Jordan, Japan, India, Nepal, Vietnam, Sri Lanka, China, and Bangladesh). Several hundred sites, covering 34 million hectares, have been designated in the list of wetlands of international importance. A key role in the creation of the Convention, and continuing technical support, is provided by the International Waterfowl and Wetlands Research Bureau (IWRB) in Slimbridge, England.

Periodically, conferences are held (Italy, 1981; Netherlands, 1984; Canada, 1987; Switzerland, 1990; Japan, 1993); these provide the Contracting Parties the opportunity to carry out some of their commitments under the Convention (accept new members and sites; review site status and pledge assistance, and so on). In 1992, an Asian Wetland Symposium, under the auspices of International Lake Environment Committee Foundation, was held in Japan in anticipation of the June 1993 conference of Contracting Parties (Isozaki *et al.*, 1993).

The Sundarbans is so far Bangladesh's only Ramsar site. It is 40,000 ha in size, making it the third largest in Asia and sixteenth largest in the world.

Convention on International Trade in Endangered Species (CITES). "Illegal trade in wildlife, including ivory and skins but excluding fish and timber, is probably the world's second largest illegitimate business (only narcotics are worth more) . . . CITES aims to eradicate illegal trade in wildlife and its products, and to ensure that future transactions are held at sustainable levels by the use of mandatory permits." (UNEP, undated).

Two Appendices attached to the Convention, periodically updated, list species that are threatened or potentially threatened by international trade. Mandated activities under the convention are coordinated by the CITES Secretariat on behalf of the contracting parties, and include administration of the mandatory permit system, plus external projects such as wildlife studies and support for realization of economic potential of properly regulated trade in wildlife.

The CITES programme in Bangladesh is implemented and monitored by the Forest Department. There is no National Committee for the country. Numerous wildlife species found in Bangladesh are currently listed in the CITES Appendices.

World Heritage Convention and *UNESCO Man and the Biosphere Programme.* Bangladesh is also a party to the World Heritage Convention, which is designed to protect cultural and natural heritage areas of outstanding universal value, and a participant in the UNESCO MAB Programme. There are no biodiversity-related measures currently active under either agreement.

2.1.3 Legislation, regulations, and standards

Wetland ownership. Permanent settlement of land dates to the 1790s for purposes of collection of revenue. Under this settlement, landed estates including forests, wetlands, and water bodies were settled on landlords (*zamindari*), and actual occupants of the land became tenants-at-will. Various reforms were introduced to curb abuses, but the system persisted until passage of the State Acquisition and Tenancy Act of 1950. With this act, the *zamindari* system was ended, and all types of rent-receiving interests in land were to be acquired by the State on payment of compensation to *zamindari* and tenants. The Act also abolished private ownership of forests,

wetlands, and water bodies. In 1956, a policy decision was taken for the Government to acquire all remaining rent-receiving interests in the country, popularly known as "wholesale acquisition of *zamindaries*". Inadequate and fraudulent land settlement records dating or dated to this period continue to hinder resource management (particularly forest management) in some areas (Appendix 6, pp. 4-6, FMP, 1992a).

Hunting and protected areas. The Bangladesh Wildlife (Preservation) Order, 1973 "provides for the preservation, conservation, and management of wildlife in Bangladesh." The law indicates if, when, how, and under what permits "game" and "protected" animals may be hunted. It makes provision for declaration of wild life sanctuaries and national parks, and indicates activities prohibited from such areas (pp. 56-58, Huq, 1991).

Pollution. The Environment Pollution Control Ordinance 1977 provides for the "control, prevention, and abatement of pollution of the environment of Bangladesh." (p. 73, Huq, 1991) This superseded the Water Pollution Control Ordinance 1973.

Forests. The Forest Act 1927 is the basic law governing public forests in Bangladesh. Wildlife exploitation within these areas are regulated by the Rules to Regulate Hunting, Shooting, and Fishing within the Controlled and Vested Forests 1959. No swamp forests are included in the government reserved and other forests, so this type of legislation has little direct linkage to wetlands. There is, however, an indirect linkage: to prevent illegal removal of public forest products, the Transit Rules made under the Forest Act prescribe *inter alia* controls on removal of timber and other products from non-Forest Department lands, including wetland swamp forests, and "it is the general impression that the Transit Rules have become an instrument of harassment" (Appendix 6, p. 9, FMP, 1992).

Fisheries. The East Bengal Protection and Conservation of Fish Act 1950 provides for the protection and conservation of fish in the inland waters of Bangladesh.

Proposed legislation. New legislation entitled Environment Protection Act is currently in preparation by the government. NERP has not yet obtained any information about it.

Water quality standards. Draft water quality standards dated late 1992 were obtained by NERP. NERP has not yet been able to confirm their current status.

2.2 THE REGION

2.2.1 Overview

The Northeast Region covers an area of approximately 24,500 sq km, bounded by the international border with India to the north and east, the Old Brahmaputra to the west, and the Nasir Nagar (to Madhabpur) and Meghna rivers to the south (Figure 1). The greater part of this region is taken up by the haor basin which comprises the floodplains of the Meghna tributaries, and is characterized by the presence of numerous large, deeply flooded depressions, known as haors, between the rivers. This vast alluvial plain possesses some 6,000 permanent shallow water bodies known as beels (usually in the lowest parts of the haors or in abandoned river channels), surrounded by large areas of seasonally flooded plains. The basin is bounded to the north by the hill ranges of Meghalaya, to the south by the hills of Tripura and Mizoram, and to the east by

highlands of Manipur. The numerous rivers rising in these hills provide an abundant supply of water to the plains and cause extensive flooding during the monsoon season, with much of the region being flooded to a depth of up to six metres. The drainage is southwest via the Surma, Kushiyara, Baulai, and Kalni rivers into the Meghna River and Bay of Bengal. Almost all land above the maximum flood level is under permanent cultivation and human settlement. There are extensive plantations and groves of trees around most villages and homesteads, and in many areas this creates an aspect of discontinuous forest.

The climate is subtropical monsoonal with an average annual rainfall of approximately 4,000 mm. Over 80% of the rain falls during the monsoon season from June to October. Temperatures normally vary between 26 and 31 C in the pre-monsoon period (Mar to May), 28 to 31 C in the rainy season, and 26 to 27 C in winter. Extreme temperatures at Sylhet in the ten-year period 1975-1984 were 6.4 and 39.3 C.

A large number of water resources development projects have been constructed (*Water Resources Development Status*, NERP, 1992) and still more are proposed for the region (*Northeast Regional Water Management Plan*, NERP 1993).

Further detailed descriptive information on the region is presented in other NERP reports (see list page ii), in particular in the *Wetland Resources Specialist Study*.

2.2.2 Wetlands and uplands

The haors, after which the region's central basin is named, are back swamps or bowl-shaped depressions between the natural levees of rivers, or in some cases, much larger areas incorporating a succession of these depressions. The haors flood to a depth of as much as six metres during the rainy season, and in many cases two or more neighbouring haors link up to form much larger water bodies. During the dry season, most of the water drains out, leaving one or more shallow lakes (beels). Many of these become overgrown with aquatic vegetation, and some dry out completely by the end of the dry season. The term beel is also used for oxbow lakes and other permanent water bodies in abandoned river channels; these are especially numerous along the lower courses of the Baulai and Kalni Rivers. As the monsoon flood waters recede during the dry season, rich alluvial soils are exposed around the margins of the beels, and these are extensively cultivated for rice.

The haor basin contains about 47 major haors and some 6,300 *beels* of which about 3,500 are permanent and 2,800 are seasonal. These wetlands vary in size from as little as a few hectares to many thousands of hectares. The principal systems are as follows:

- Baram, Banka, Habibpur, Maka, and Makalkandi haors, which unite to form a single large water body during the rainy season; the Ghulduba haors; and Ranga and Baudha beels. Located in the eastern and lowest part of the basin in Mymensingh.

- Tangua, Shanir, and Matian haors in the deep northern basin at the foot of the Meghalaya Hills. These form a single water body during the rainy season.

- Dekhar Haor, Pathar Chanli Haor, and Jhilkar and Jhinkar Haors, to the east of the Tangua system.

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- The Jamaikata, Mahai, Nalua, and Parua haor system, on the eastern rim of the basin.
- Hakaluki, Chatal Bar, Haila, Kawadighi, Pagla and many smaller haors, in the central Sylhet lowlands.
- Hail Haor, between the Tarap and Banugach hill ranges in the southeast.
- Dingapota, Ganesher, Tolar, Anganer, Bara, and Humaipur Haors, in the south of the basin.
- Etna and Sania Haors, Kishorganj district.
- Khaliaghuri Haor, east Mymensingh.

Currently, the haors, beels, and ponds support major subsistence and commercial fisheries, the seasonally flooded plains support a major rice-growing industry, and the abundant aquatic vegetation provides rich grazing for domestic livestock and a source of fuel, food and fertilizers for the local people. The wetlands are home to a very wide variety of resident and migratory waterfowl, including an estimated 100,000 to 150,000 ducks, and provide a refuge for many other species of wildlife which are becoming increasingly rare elsewhere in Bangladesh.

Hilly upland or piedmont areas fringe the region to the north, east, and southwest. Some of the areas are under private cultivation, mainly tea, and some under Forest Department ownership.

2.2.3 Natural history

There has been mass extinction of the native flora and fauna of the haor basin of Northeastern Bangladesh. In its original form, the basin would have consisted of a rich mosaic of permanent and seasonal lakes and ponds with abundant aquatic vegetation, surrounded by vast areas of swampy ground with tall reeds and seasonally flooded grasslands. Swamp forest, dominated by *Barringtonia*, *Pongamia*, and other flood-tolerant tree species, would have covered the river levees, and provided a secure refuge for terrestrial wildlife during the monsoon floods. On higher ground, this would have given way to scrub jungle and dense stands of bamboo.

Wildlife would have been abundant. Marsh Crocodiles and Otters would have been common in every lake and swamp. One-horned Rhinoceroses, Wild Buffalo, and Swamp Deer would have grazed in the marshes, and Asian Elephants, Gaur, Sambar Deer, Hog Deer, and Wild Boar would have roamed the forests and tall grasslands. Tigers and Leopards would have been common, along with many smaller predators such as Wolves, Jackals, and several species of wild cat. And everywhere, there would have been birds — teeming flocks of migrant ducks and shorebirds from Siberia mingling in winter with the resident flocks of cormorants, pelicans, herons, egrets, storks, ibises, whistling-ducks, comb ducks, pygmy geese and many more species. During the breeding season, there would have been huge mixed colonies of cormorants, herons and storks in the patches of forest, while the marshes would have rung with the bugling calls of Sarus Cranes.

Today, although most of the permanent water bodies have survived, all other ecosystems have almost completely disappeared. Vast areas of the seasonally flooded plains have been converted to rice monoculture, while areas less suitable for rice are now heavily grazed by domestic

livestock or cultivated for wheat and other crops. The swamp forests have been reduced to a few small patches, often no more than ten or twenty widely scattered and now very old trees, while virtually all land above the level of the monsoon floods has been utilized for permanent settlement, homestead forests, and public infrastructure. The swamp forests, scrub jungle, bamboo thickets and dense stands of reeds have disappeared almost without trace.

Although we have no good contemporary accounts of the haor basin in its natural condition, we can gain an impression of how it would once have appeared by visiting comparable areas in neighbouring countries where these ecosystems still survive in more or less their natural form. Kaziranga National Park and Manas Wildlife Sanctuary in Assam and Royal Chitwan National Park in Nepal still retain outstanding examples of floodplain wetland ecosystems and their associated forest communities, and provide a vivid contrast to the totally man-modified environments which now exist over most of the plains of the Ganges and Brahmaputra systems. Indeed, these three large and well-protected sanctuaries have become critical to the continued survival of a whole group of wildlife species which have now become extinct over most of their former ranges. These include the One-horned Rhinoceros *Rhinoceros unicornis*, Swamp Deer *Cervus duvauceli*, Hispid Hare *Caprolagus hispidus*, Swamp Partridge *Francolinus gularis*, Bengal Florican *Eupodotis bengalensis* and Marsh Babbler *Pellorneum palustre* — all now listed as threatened in the Red Data Book (IUCN, 1990a).

2.2.4 Key biodiversity assets

The key biodiversity assets of the Northeast Region include:

- The remaining major freshwater wetland ecosystems, in particular nine that are identified as of international significance,
- Internationally migrating and resident waterfowl (386,000 counted in January 1993),
- The threatened swamp forest, floodplain grassland, and reed land ecological communities (habitats),
- A number of threatened lowland plant and animal species, and
- Upland ecosystems, communities, and species.

Overlap within this hierarchy is, of course, considerable: ecosystems harbour species which are dependent on particular habitats. In addition to the extant biodiversity elements listed above, there are elements which have already been extirpated from the region. For these, species and habitat restoration may be an option, if benefits warrant it and costs are acceptable; social, biophysical, and economic factors must all be considered.

Key wetland ecosystems

The Northeast Region contains all of the nation's remaining large semi-natural freshwater wetlands, a landscape once characteristic of much of the country. In particular, nine wetland sites were found to meet Ramsar criteria for international significance (Table 2.2). The locations of these sites are shown in Figure 2, which also shows areas of fisheries importance, threatened community sites, and Forest Department-owned upland areas. These sites are described briefly below. The *Wetland Resources Specialist Study* describes them in further detail.

Table 2.2a: Ramsar Convention Criteria for Wetlands of International Importance

Ramsar Convention
The Ramsar Convention states that:

> "Each Contracting Party shall designate suitable wetlands within its territory for inclusion in a 'List of Wetlands of International Importance.' - Article 2.1
>
> "In the first instance, wetlands of international importance to waterfowl at any season should be included. . . . [and also wetlands of] international significance in terms of ecology, botany, zoology, limnology, or hydrology." - Article 2.2

Montreux Conference of the Contracting Parties
Criteria for identifying wetlands of international importance were subsequently formulated and approved at the Montreux Conference of the Contracting Parties (Montreux Proceedings, Vol.1, Annex I, Rec. C.4.2 (Rev.)).

Criteria
A wetland is identified as being of international importance if it meets at least one of the criteria set out below:

1. *Criteria for representative or unique wetlands.* A wetland should be considered internationally important if:
   a. It is a particularly good representative example of a natural of near-natural wetland, characteristic of the appropriate biogeographical region; or
   b. It is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region; or
   c. It is particularly good representative example of a wetland which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position; or
   d. It is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.
2. *General criteria based on plants or animals.* A wetland should be considered internationally important if:
   a. It supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species; or
   b. It is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna; or
   c. It is of special value as the habitat of plants or animals at a critical stage of their biological cycle; or
   d. It is of special value for one or more endemic plant or animal species or communities.
3. *Specific criteria based on waterfowl.* A wetland should be considered internationally important if:
   a. It regularly supports 20,000 waterfowl; or
   b. It regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetland values, productivity or diversity; or
   c. Where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.

Table 2.2b: Ramsar Convention Criteria for Wetlands of International Importance (cont')

Guidelines for Application of the Criteria

To assist Contracting Parties in assessing the suitability of wetlands for inclusion on the List of Wetlands of International Importance, the Conference of the Contracting Parties has formulated the following guidelines for application of the Criteria:

a. A wetland could be considered of international importance under Criterion 1 if, because of its outstanding role in natural, biological, ecological or hydrological systems, it is of substantial value in supporting human communities dependent on the wetland. In this context, such support would include:

- provision of food, fibre or fuel;
- or maintenance of cultural values;
- or support of food chains, water quality, flood control or climatic stability. The support, in all its aspects, should remain within the framework of sustainable use and habitat conservation, and should not change the ecological character of the wetland.

b. A wetland could be considered of international importance under Criterion 1, 2 or 3 if it conforms to additional guidelines developed at regional (e.g. Scandinavian or West African) or national level. Elaboration of such regional or national guidelines may be especially appropriate:

- Where particular groups of animals (other than waterfowl) or plants are considered more suitable as a basis for evaluation; or
- Where waterfowl and other animals do not occur in large concentrations (particularly in northern latitudes);
- or where collection of data is difficult (particularly in very large countries).

c. The "particular groups of waterfowl, indicative of wetland values, productivity or diversity" in Criterion 3(b) include any of the following:

- loons or divers: **Gaviidae**;
- grebes: **Prodicipedidae**;
- cormorants: **Phalacrocoracidae**
- pelicans: **Pelicanidae**
- herons, bitterns, storks, ibises and spoonbills: **Ciconiiformes**;
- swans, geese and ducks (wildfowl): **Anatidae**;
- wetland related raptors: **Accipitriformes** and **Falconiformes**
- cranes: **Gruidae**
- shorebirds or waders: **Charadrii**; and
- terns: **Sternidae**.

d. The specific criteria based on waterfowl numbers will apply to wetlands of varying size in different Contracting Parties. While it is impossible to give precise guidance on the size of an area in which these numbers may occur, wetlands identified as being of international importance under Criterion 3 should form an ecological unit, and my thus be made up of one big area or a group of smaller wetlands. Consideration may also be given to turnover of waterfowl at migration periods, so that a cumulative total is reached, if such data are available.

The list discussed here is not, of course, comprehensive. Further study of other biophysical topics and processes or in greater depth or detail might well show that other regional wetlands also meet Ramsar criteria for international significance. Also, though Bangladesh has not established criteria for nationally significant wetlands, it is clear that many sites would qualify given any reasonable set of criteria.

1. *Tangua Haor* is perhaps the most natural large wetland remaining in the Northeast Region. It possesses extensive stands of emergent marsh vegetation, with little human settlement in the immediate vicinity and significant areas of higher ground between the beels which are not under cultivation and are supporting some natural herbaceous vegetation. This haor is the core of the northern haor system, which together held 40% of all waterfowl recorded during the February/March 1992 survey. Tangua Haor has also been identified as the single most important major fish production and dispersal centre or mother fishery in the region. The term 'mother fishery' is used by local fishermen to refer to sites characterized by densely concentrated, diverse, high-quality fish habitats (deep river scour holes, called duars, clear tributary streams, deep beels, sediment-free khals) and supportive flora (swamp forest, reed swamp, floodplain grasslands). Five mother fisheries have been identified in the region (see *Fisheries Specialist Study*).

2. *Pasua Beel, Gurmar Haor* is surrounded by the finest stands of natural floodplain vegetation in the region. These include a dense stand of *Pongamia pinnata* koroch, large areas of reeds *Phragmites kharka* nol, and patches of dense shrubbery. The importance of Pasua Beel in a regional context is quite outstanding. It contains what would appear to be the best remaining examples of the *Pongamia* forest and tall grassland ecosystems in the region. It provides secure roosting for huge numbers of cormorants, herons, and egrets (at least 4,600 in late April 1992) and supports a number of bird species which are scarce elsewhere in the region. Concentrations of Pallas's Fish Eagle, a globally threatened species, are of great significance. The site supports a much higher diversity of waterfowl and other wetland birds than any other site investigated, with surveys finding 56% of all regional waterfowl species at this site.

3. *Hakaluki Haor* has long been known as a major wintering area for migratory waterfowl, especially ducks, and is a popular duck-hunting area for sportsmen from Dhaka. Despite high levels of disturbance from hunting and fishing, the site remains very important for wintering ducks and migratory shorebirds. The site is also a mother fishery.

4. *Hail Haor* has biodiversity value primarily with regard to its unique status in the region as the largest shallow permanent lake. The lake supports a very rich and diverse aquatic plant community, which in turn supports a wide variety of resident bird species, several of which are scarce elsewhere in the region. The site would undoubtedly be of great importance for wintering waterfowl were it not for the high levels of disturbance from fishing activity.

5. *Khaliajuri Area* is a relatively undisturbed area representative of the deeply flooded zone, and has also been identified as a mother fishery. The area has some swamp forest patches, and in the dry season extensive areas of winter grasses such as *Hematheria protensa* chailla. The rot resistance of this species' cuttings make it the material of choice for homestead erosion protection: villagers gather it, pile it up on the homestead margins, and fix it in place with bamboo frames.

6. *Companiganj Area* contains the best reed swamp habitat remaining in the region and also has some floodplain grassland, which may be habitat for one or more threatened passerine bird species. It has been identified as mother fishery. Otters and large concentrations of turtles have been observed.

7. *Bara Haor* contains the best floodplain grassland habitat remaining in the region, and some reed swamp and swamp forest areas. Breeding cormorants and breeding herons have been observed. As at Companiganj Area, the floodplain grassland may be habitat for one or more threatened passerine bird species.

8. *Kawadighi Haor* remains very important for a wide variety of waterfowl, despite the changes which occurred to these wetlands since the construction of the Manu River Project in 1976-83. In particular, shallow beels with large areas of rotting aquatic vegetation and exposed mud provide attractive habitat to shorebirds; 16% of the February/March 1992 regional total were found at this site, along with 27% and 17% of the heron and egret totals. Some of the beels are or may be important as breeding sites for two species not previously seen breeding in Bangladesh; in particular, Whiskered Tern nests were found in June/July 1993, and Black-winged Stilts were observed courting and nest-building. Prior to the construction of the flood control project, it was a mother fishery. The scope for habitat rehabilitation, and for modified flood control project operation in support of this, are key issues at this site.

9. *Balai Haor* was flagged on the basis of the presence of two threatened bird species, Lesser Adjutant and Pallas's Fish-Eagle; and of large concentrations of mostly resident ducks during periods of flash flooding (32,000 were present in late March 1992). The site may have some importance as a staging area for passage migrants, because of its strategic position as the first or last major wetland on the way to and from the region. The site is more heavily utilized by humans, habitats are more degraded, and conditions in general are less unique than at the first seven mentioned above. Further study will be necessary to determine whether this site warrants the same level of effort to improve management as at the other internationally significant sites, or whether it should more properly be classified as a nationally significant site.

Internationally migrating and resident waterfowl

The most comprehensive ornithological surveys of the haor basin were undertaken by NERP during the period February 1992 to January 1993. These surveys show that, despite massive habitat losses, the basin remains an internally important wintering area for migratory water fowl, principally ducks and shorebirds. The region is also of some importance for passage migrants in spring, and perhaps also in autumn, at least for two shorebird species, Ruff (an early migrant) and Asiatic Golden Plover. Large numbers of some resident species are still in evidence, notably Little Grebe, Little Cormorant, a variety of herons and egrets, both species of whistling-duck, both jacanas, and other species. Additional information is given in the *Wetland Resources Study*.

Threatened habitats

Three of the lowland ecological communities were found to be threatened: fresh water swamp forest, floodplain grassland, and reed swamp.

1. *Fresh water swamp forest* consists of flood-tolerant evergreen trees. A fully-developed stand exhibits a closed canopy with mature trees standing ten to twelve meters tall. *Barringtonia*

acutangula (hijal) and *Pongamia pinnata* (koroch) occur in varying proportions to form this vegetation type, accompanied by a number of other tree species in lesser numbers. The community is adapted to monsoon flooding to depths of 0.5 to 2.5 m for three to four months; thus, much of the area now under or suitable for monsoon rice would once have been occupied by swamp forest. The trees mostly produce their seeds in the monsoon period and disperse them through the water; seedlings grow in great quantities. Remnant patches are now restricted to areas sloping away from village highland down towards the haor, helping to shelter homesteads from wave erosion; to elevated ridges between beels; and to stream levees. These patches currently vary from a few plants to several hectares of more than a thousand trees. The luxuriance of the vegetation also varies, from sparse low trees with undergrowth grasses, to dense closed canopy with poor undergrowth, depending on local conditions, particularly the extent of human disturbance.

Swamp forest has been so nearly eradicated that in 1989 an analysis of the dendrological regions of Bangladesh, carried out in association with the FAO land resource appraisal for agriculture (1988), could state that all areas inundated for most or all of the wet season are unsuitable for any tree species. Admirably, the Bangladesh Forest Research Institute quickly corrected this impression in *Trees for Lowlying Areas of Bangladesh* (Alam *et al.*, 1991).

2. *Floodplain grassland* prefers reasonably well-drained land affected by flooding of fairly short duration, typically found in plain lands between a haor basin and steep hills. The community consists of various medium to high grasses. The most dominant species is *Vetiveria zizanioides* (binna), which in the extreme case can be virtually the only species present. Other associated species are *Phragmites karka* (khagra, nol), *Saccharum spontaneum* (khag), *Sclerostachya fusca* (khuri), and *Arundo donax* (baranol). Small annual grasses, herbs, and *Cyperus* are common in the dry season. The presence of tree seedlings and scattered older trees suggests that the grassland community may not be a climax type, though the succession process seems to be very slow. Formerly this was a key habitat for rhinoceros and other large mammals; in addition, a number of small bird species, some extant and some already extinct in the region, depend fully on it.

3. *Reed swamp* (panjuban) is adapted to lands intermediate in height between the haor basin and homestead lands (kanda), typically on ridges out in the haors. These areas are fairly deeply flooded during the flood season and dry out during the dry season. It consists of the grasses *Phragmites karka* (khagra, nol) and *Saccharum spontaneum* (khag, aisha). Some sedge/meadow grasses are also found here in lesser amounts, plus some woody shrubs. Mature reeds attain heights of six to seven metres, in earlier times affording important habitat for rhinoceroses, barashinga, Bengal Tiger, and Asian Elephant. The community is composed principally of perennials, making it particularly vulnerable to utilization pressure, though sustainable harvesting is possible if a rotation of at least three years is allowed. Reclamation of land for agriculture and indiscriminate reed cutting for building material, industrial raw material, and fuel, particularly for lime-burning, has all but eliminated the once vast reed swamps of the region. Reed swamp is the preferred habitat of Bengal Rose *Rosa involucrata* gunja kata, a species believed to be globally threatened.

Threatened lowland species

The bird, mammal, reptile, amphibian, and macrophyte species known or thought to have occurred in the lowlands of the region, plus some (mainly bird) upland species, are listed in Annex B. (Fish species are covered in the *Fisheries Specialist Study*).

The historic mammal, reptile, and amphibian fauna of the region's lowlands is thought to consist of 89 species in 37 families. The 370 bird species listed here are those observed by NERP during extensive lowland studies and much more limited upland studies; plus 36 waterfowl species believed present now or previously. The wild macrophytes of the region's lowlands consist of at least 216 species, including nine exotics.

Biodiversity conservation at the species level logically focuses first on those species which are globally threatened or globally commercially threatened; prevention of the loss of these species, irreversibly and forever, is urgent. Table 2.3 lists the globally threatened and commercially threatened species of the region's lowlands. As the table indicates, some of these species still occur in the region and some are known or thought to be regionally extinct. This list is based on (1) the Red Data Book (IUCN, 1990a), (2) plus known changes to be incorporated in the next edition; (3) CITES Appendix I or II; plus (4) one turtle and two macrophyte species not listed in either RDB or CITES but believed by NERP to be globally threatened. Only threatened species in the taxa noted above are included here.

A number of species are known or thought to be regionally extinct but are not listed as globally threatened. These are: Common Crane, Black-necked Stork, Black Ibis, Painted Stork, Woolly-necked Stork, and Wild Boar (still occurs as a domestic animal). In addition, Great Cormorant, Black-crowned Night Heron, Grey Heron, and Black-headed Ibis still occur in the region but no longer breed there.

Table 2.3: Threatened species

Group/Name	RDB	CITES		Reg Ex?
		I	II	
BIRDS				
Pink-headed Duck	Ex			x
Spot-billed Pelican	I			x
Dalmatian Pelican	E			x
Oriental White Stork	R			x
Marbled Teal	V			x
Swamp Francolin	V			x
Bengal Florican	E			x
Greater Adjutant	E			x
White-winged Wood Duck	V			x
Lesser Adjutant	V			x
White-bellied Heron	E			x
Baer's Pochard	V			
Pallas's Fish Eagle	R			
Jerdon's Moupinia	V			
Black-breasted Parrotbill	I			
Swamp (Long-tailed) Prinia	R			
Blyth's Kingfisher	I			
Marsh Babbler	K			
MAMMALS				
Indian Pangolin			x	
Hispid Hare	E	x		
Freshwater Dolphin	V	x		
Bengal Fox	I			
Common Otter		x		
Smooth Indian Otter	K		x	
Small Indian Civet			x	
Jungle Cat			x	
Fishing Cat			x	
Leopard	E	x		x
Tiger	E	x		x
Asian Elephant	E	x		
Sumatran Rhinoceros	E	x		x
Javan Rhinoceros	E	x		x
Great Indian Rhinoceros	E	x		x
Pygmy Hog	E	x		x
Gaur	V	x		x
Wild Buffalo	E			x
Swamp Deer	E	x		x

The conservation status of other classes of animal life and of microphytes has not yet been investigated.

The appropriate interventions to assist each globally threatened or commercially threatened species depend on the current regional status of the species, its dependence on habitats and other wild species, its relationships with humans, and other aspects of its life cycle. These considerations for each of the threatened/ commercially threatened species of the Northeast Region are discussed further in Chapter 6.

Upland biodiversity

Some parts of the region's upland areas, principally those on Forest Department land, retain some ecological character as natural forest ecosystems. As such, they are important national biodiversity havens for purely upland species and for some species which migrate locally between upland and lowland/wetland areas.

The Rema-Kalenga Wildlife Sanctuary, the only designated Protected Area in the region, gazetted in 1981, contains the last remaining patch (nominally 1,036 ha) of primary forest in the Sylhet region (IUCN, 1990b). Another forested area, Lawa Chara, has been proposed for National Park designation.

Table 2.3: Threatened species (cont')

Group/Name	RDB	CITES		Reg Ex?
		I	II	
REPTILES				
Malayan Box Turtle	CT*			
Spotted Pond Turtle	I/V*	x		
Sylhet Roof Turtle	I/R*			
Common Roof Turtle		x	x*	
Bengal Eyed Turtle	CT*			
Ganges Soft Shell		x		
Peacock Soft Shell		x	x*	
Narrow-headed Soft Shell				
Flapshelled Spotted Turtle		x	x*	
Bengal Grey Lizard		x		
Yellow Common Lizard	I	x		
Rock Python	V	x		
Marsh Crocodile	V	x		x
AMPHIBIANS				
Bull Frog			x	
MACROPHYTES				
Bengal Rose				
Eurayle ferox				

RDB: Ex = extinct, E = endangered, V = vulnerable, R = rare, I = indeterminate (known to be E, V, or R), K = insufficiently known, CT = commercially threatened.
* = category to appear in next edition.
Reg Ex? = known/thought extinct in the region.

The most recent Working Plan of the Forest Department Eastern Division, which covers Forest Department lands in the Northeast Region, is seventeen years old and almost seven years out of date, having been prepared in 1977 to cover the ten year period 1977 to 1987. Thus, in keeping with a traditional perspective on tropical forest resource management, nearly all Forest Department land is still earmarked for economic forestry activities. In particular, clear-cutting and conversion to plantation monoculture are still accepted options for natural mixed forest areas. In recent years, as the value of tropical forest biodiversity becomes more widely recognized internationally, attitudes towards logging and other forestry practices have undergone major shifts. Despite this, the recent Forestry Master Plan (FMP Project, 1993) did not definitely set aside any additional forest areas for purposes other than economic forestry in general and clear-cutting in particular, despite advocacy of such approaches by conservationists and proponents of locally-based participatory approaches to forest management, though the FMP plan document did express thematic recognition of the existence of these alternatives.

Interactions between natural biological systems and human communities: utilization and management

In the Northeast Region, human communities are, and have been for millennia, an integral part of natural biological systems such as wetlands and upland forest. Interactions between human communities and these systems are complex and important to both sides. The main human pressures on natural biological systems have been conversion of natural habitats to cultivated fields and hunting/gathering for subsistence, commercial, or sport purposes.

In addition to the products and services gained through these activities, natural biological systems provide a range of less visible services which may be taken for granted until problems arise as a result of human modification of the landscape — services such as water purification, erosion control, flood storage, regulation of soil fertility, agricultural pest control, recreation, aesthetic beauty, and religious and cultural functions. Finally, some wild species function as pests or threats to humans and human activities.

Each of the biodiversity assets described above is subjected to particular patterns of human utilization and management. These are described and analyzed (in terms of driving forces, strengths, weaknesses, opportunities, threats) in the *Wetland Resources Specialist Study*.[1] From NERP's studies to date of these patterns, certain general statements can be made. These patterns are dynamic, exhibiting changes over time, some gradual, some more sudden; participation of many actors; with many different motivations; oriented to very different time-frames; pursuing widely different ends. Land tenure *de facto* and *de jure* are extremely important. Changes in the patterns over time reflect driving forces in the world at large and on the local scene, such as *inter alia* population pressures, trade and markets, and international and national policies. Actors include local residents, migrants and visitors, and agents (officials, contractors, lessees) of local and central government agencies and projects. Motivations include subsistence, commercial (cash income), and sport/recreation. Management decision time-frames range from immediate, one-time gratification to many generations of sustainable, recurrent harvests.

Indigenous traditional locally-based management systems still exist in the region, though with declining importance. Mosque-based hijal forest management involves local participation in management of community forests and reflects the concept of sustainable resource utilization. Garubala is a term used in the region to describe the system of community management of livestock. These community management systems within the wetlands are under threat because of shifts in the social power structure and because of conflicts at the political level. Communities and individuals are experiencing great hardship as a result of wave erosion after swamp forests are cleared by outsider fishery lessees, of degradation of traditional sources of wild foods and medicines, and of decreasing supplies of biomass for fuel and fodder.

A traditional method for conserving natural biological resources is the protected area or national park. In the classical national park approach, the central government takes over the management of valued areas, regulating or excluding traditional users. Results outside the industrialized countries have had limited success however. Adequate enforcement is simply beyond the financial and institutional means of developing countries, when faced with the exploitation

[1]The existing draft version of this study will be revised to include major new sections dealing with this topic based on the 1993/4 field work.

pressures of both traditional users and of outsiders, such as individual poachers and 'influentials' who engage in commercial logging and similar activities.

In the 1980s, alternative models based on local participation began to be implemented. In a recent paper (Wells and Brandon, 1993), a total of 23 existing 'integrated conservation development projects' (ICDPs) were reviewed. Each project has the objective of 'enhancing biodiversity conservation through approaches which attempt to address the needs, constraints, and opportunities of local people.' The main conclusions of the authors were that:

- ICDP experience so far has fallen short of expectations, but the 'approach must be reinforced and expanded simply because there seem to be no other choices.'

- The authors infer that ICDPs are more complex undertakings than was originally thought; and that successful achievement of biodiversity objectives will require substantial, long-term commitment, and a willingness to innovate and experiment. Most current ICDPs have been operational for less than five years, and many are operating on very modest budgets 'while attempting to promote ambitious and wide-ranging programs aimed at poverty mitigation, environmental education, and conservation in numerous communities spread over large areas. These projects must be regarded as demonstration projects [that cannot alone] contribute significantly to biodiversity conservation.'

- While the early ICDPs dealt with the issue of local participation, there was a failure to recognize that success was also contingent upon other, external factors:

  — 'Adequate political commitment to the ICDP from local authorities, influential local leaders, and high levels within relevant agencies of the national government'

  — 'Where appropriate, new and workable management structures should be empowered to represent different national and local interests involved in the ICDP' and any necessary legislation passed authorizing the ICDP to carry out certain functions

  — Land tenure and resource access should be clarified and secured, to support local residents in shifting towards longer-term perspectives

  — ICDPs should be coordinated with other development efforts

  — Government agencies involved in protected area management require reorientation toward a more people-oriented approach, in addition to more conventional strengthening

The NEMREP biodiversity component meets the definition of an ICDP, and was designed with the above considerations in mind to the degree possible. The developing literature on ICDP experience should be monitored during NEMREP implementation for additional lessons learned.

2.2.5 Regional surface water quality

Surface water quality is of serious concern, nationally and in the Northeast Region. The most urgent concern is the public health impact of domestic waste contamination of surface water. Water-borne disease is common; so much so that it is the main cause of death of children under

five years of age. The reasons for this are clear: in rural areas the prevalence of sanitary latrines areas is low (15% of households) and tube well access, though improving, is far from universal; in towns sewage collection, wastewater treatment, and properly-managed solid waste (garbage) disposal sites are non-existent.

The surface waters of the region also suffer from industrial pollution. There are many industrial facilities in the region that discharge untreated liquid effluents into surface water: textile industries, oil and gas facilities, fish- and tea-processing plants, and the Kraft process Sylhet Pulp and Paper Mill (SPPM). The ammonia fertilizer plant at Fenchuganj, formerly a significant pollution source, has exceeded its intended service life and was ordered closed down in December 1992 (actual closure has been delayed until Dec 1993 due to local opposition; a new plant is planned for the site). Discharges from the pulp mill and the fertilizer plant are known to have caused fish contamination and kills in the deep water upper reaches of the Surma and Kushiyara Rivers. In particular, the mill reportedly discharges more than 550 kg of mercury annually, a highly toxic heavy metal.

The national industrial sector grew 5.9% in fiscal 1991, and the national target for FY93 is 9 to 10%. These values are probably reasonably representative for the region, keeping in mind that much of its current and future industrial base will be sited in the southwest in the Dhaka peri-urban zone. If water quality management is aggressively strengthened, the environmental impacts of industrial growth need not be onerous; but if strong management is not put in place soon, enormous public health, fisheries, and other problems will likely result.

Agrochemical pollution is also of concern, though current levels of pesticide and fertilizer usage are very low (0.27 kg/ha and 95 kg/ha), even by developing country standards. A recent study of fish flesh from sites in other regions of Bangladesh found quite low levels of pesticide contamination (FAP 17, 1992). Even so, reduced fish production and increased fish disease are observed to occur in certain situations, in particular within FCDI projects that have significantly increased water residence time (that is, stagnation or reduced flushing, and increase agrochemical use associated with increased HYV boro cultivation). Acute pesticide poisoning due to improper handling and disposal of containers is a problem.

Existing data on surface water quality in the region is very limited. Department of Environment (DOE) data for the region consists of:

- River water quality monitoring of six parameters (biological oxygen demand, total solids, dissolved oxygen, chloride, pH, and turbidity) at five sampling sites, two within the region (on the Surma at Chhatak and on the Meghna at Ashuganj) and three on the region's southern boundary rivers (on the Lakhya at Ghorasal and Narayanganj, and on the Meghna at the Meghna ferry ghat; Reazuddin *et al.*, 1992), plus

- Sampling of selected industrial effluent and drinking waters.

This level of information is insufficient to support analyses of the impacts of poor water quality nor, by extension, the impacts of efforts to improve it.

2.3 INSTITUTIONS

The purpose of this section is to establish the general institutional background for NEMREP.

2.3.1 Government agencies

Wildlife Conservation and Protected Areas Management: Forest Department

In 1973, a Wildlife Circle was established in support of the wildlife preservation legislation passed in that year. In 1976, a Wildlife Advisory Board was established under that legislation. The Wildlife Circle "operated until 1983, when it was disbanded due to budgetary constraints following a review by the Enam Committee. The majority of the 112 staff of the Circle were merged into other operations within the Forest Department." In 1985, in response to a request from the Wildlife Advisory Board, "the Government appointed a Task Force composed of members from inside and outside Government to examine the current status of wildlife, identify causes for its depletion, and suggest appropriate arrangements to improve conservation." The Task Force reported in June 1986 and recommended *inter alia* that the existing protected area system be consolidated and augmented, and that a wildlife and protected areas management organization be created within the Forest Department (Wildlife Task Force, 1986). No action has been taken on any of the significant Task Force recommendations (all quotes and conclusion are from AWB, 1991, pp. 13-14).

Of the numerous nominally protected areas in the country, staff with roles defined to include protected area management are on station only in the Sundarban and in Bhawal National Park 40 km north of Dhaka.

As was mentioned above, the CITES programme in Bangladesh is implemented and monitored by the Forest Department, which participates in meetings of the parties to the Convention, provides documentation to animal traders, and imposes bans on prohibited items.

Wetland ownership: Ministry of Land and Forest Department

The large freshwater wetlands of the Northeast are owned almost entirely by the Ministry of Land. This agency is mandated to raise revenue from its land assets, and this is mainly accomplished through renting or leasing use rights of various types, such as fishing rights through the District Commissioners' offices. Neither MOL nor the Dcs have a mandate for or expertise in resource management, or any history of contact with donor agencies or donor-funded technical assistance.

MOL can assign the leasing function to other government agencies. The best known example is the assignment of small fisheries (<8 ha) lease sales to local government. MOL receives a nominal fee in recognition of its ownership.

MOL has on previous occasions entered into management agreements with resource management agencies. The best known example is an agreement with the Forest Department to afforest coastal *char* lands.

In 1973, Sylhet Pulp and Paper Mill took possession from the Forest Department of about 50,000 ha of land nominally under reed forest to provide raw materials for the mill, but this was unsuccessful. As a result, in early 1993, SPPM proposed to return this area to the Forest

Department in exchange for 20,000 ha of land at higher elevation. Negotiations between SPPM and FD are ongoing.

Land tenure disputes, with some court cases originating in documents dating or date to Independence, and ongoing encroachment of MOL and FD land are important problems.

Water Quality Monitoring and Pollution Control: Department of Environment, Department of Public Health Engineering, Municipal Corporations, and Bangladesh Chemical Industries Corporation (BCIC)

Department of Environment. The Environment Pollution Control Board and Environment Pollution Control Cell was established in support of the Environment Pollution Control Ordinance 1977 with responsibilities limited to pollution control aspects.

Environment pollution control projects were initiated in 1978 by appointing five divisional officers with a working force of 118 personnel. The offices were: Dhaka Division, Dhaka; Research Laboratory, Dhaka; Chittagong Division, Chittagong; Khulna Division, Khulna; and, Rajshahi Division, Bogra. The main objectives were:

- Surveying industrial units and identifying the industries creating pollution.
- Reducing air and sound pollution.
- Collecting water samples from rivers, lakes, and samples of ground water for testing their quality.
- Testing the water supplied to major towns and implementing pollution control rules and laws.
- Acting upon public complaints.
- Surveying river water and coastal area water for taking pollution control measures.
- Taking necessary action against waste dumping.
- Surveying and researching bio-gas production.

Between 1978 and 1985, the Environment Pollution Control Cell was funded under the development budget. In 1985, a Department of Environment Pollution Control (DEPC) was established under the GOB revenue budget. It has four divisional offices (Chittagong, Khulna, Rajshahi, and Dhaka) with eleven staff each, plus 14 head office staff in Dhaka. Each of the divisions has a laboratory to undertake necessary tests and analysis. Major achievements included:

- Relocation of tanneries from the Buriganga River
- Ban on toxic waste imports
- Preparation of national environmental quality standards (DOE, 1991b)
- Prevented registration of eight harmful pesticides
- Identified 2072 industries causing pollution through a survey of 5967 industries
- Collected water samples from 27 rivers, analyzed these and established a data bank
- Collected and analyzed 434 ground water samples
- Established 379 bio-gas plants

In 1990, the Ministry of Environment and Forests was created, composed of two departments, Environment and Forestry. Within it, DEPC became the Environment Pollution Control

Directorate. Recent activities include preparation of new water quality standards and a project to collect and analyze surface water samples from each district.

Department of Public Health Engineering (DPHE). The Department of Public Health Engineering is responsible for rural water supply and sanitation.

Municipal Corporations. The Municipal Corporations in each major urban centre are responsible for urban infrastructure, which includes urban water supply and sewage conveyance and treatment systems, development zoning, and so on.

Bangladesh Chemical Industries Corporation (BCIC). The Bangladesh Chemical Industries Corporation, under the Ministry of Industries, is by far the largest public sector industry, with 22 enterprises, including four pulp and paper mills, and employing over 30,000 people to produce a wide range of products.

2.3.2 Regional governmental associations

The South Asian Association for Regional Cooperation (SAARC), which has as members Bangladesh, Bhutan, India, Nepal, Maldives, Pakistan, and Sri Lanka, is in the process of setting up a Technical Committee on Environment.

In addition to this, formation of a specialist Regional Wetlands Committee and a SAARC Environmental NGO Network were suggested in the *Recommendations on a [Regional] Environmental Action Plan - for Consideration by SAARC Summit*, prepared at a November 1992 meeting of the Bangladesh, India, Nepal, and Pakistan members of the Global 500 Forum (established at Rio di Janeiro in 1992 to "link the members of UNEP's Roll of Honour"). As far as NERP can ascertain, this document has not been officially acknowledged by SAARC. Some environmental issues were discussed at the Summit, which took place in April 1993, but wetlands were not.

2.3.3 Non-governmental organizations and the private sector

NGOs active in Bangladesh in areas directly relevant to NEMREP concerns are described here. It should be noted that many other NGOs are active in the region, and in the areas of biodiversity and surface water quality management.

International and regional NGOs

Several international and regional NGOs have played key roles in the creation of international and regional agreements, resources, and fora which have been of immeasurable value in assisting Asian countries, including Bangladesh, to address national biodiversity concerns. Each of these organizations will likely to continue to serve in this capacity.

International Union for the Conservation of Nature. IUCN, founded in 1948 with the sponsorship of France, UNESCO, and the Swiss League for the Protection of Nature, is an umbrella organization whose members include 61 state, 128 government agencies (more than half are developing countries), and most of the major non-governmental conservation organizations such as the national branches of the World Wide Fund for Nature (formerly World Wildlife Fund). It is the largest international group concerned with natural resource management. Asia regional office in Bangkok 1991. Regionally, IUCN activities include publication in 1990 of the *Directory*

of Asian Wetlands; and sponsorship in December 1991 of the *International Conference on Waterfowl and Wetlands* in Karachi (Scott, 1992).

IUCN has been active in Bangladesh since 1985, and established a country office here in 1989. IUCN has been involved in the preparation of the National Conservation Strategy for a number of years; and co-sponsored a *National Workshop on Sustainable Management of Freshwater Wetlands in Bangladesh* (December, 1992).

International Waterfowl and Wetland Research Bureau. IWRB, founded in 1954, has a small staff which stimulates and coordinates waterfowl and wetland activities worldwide. It played a key role in the creation of the Ramsar Convention, to which it continues to provide technical support. IWRB's Waterfowl Division coordinates the monitoring of waterfowl populations in over 90 countries (including Bangladesh) through the International Waterfowl Census (IWC). The results of these, and of other studies coordinated through the research group, are used to formulate management plans for waterfowl populations and recovery plans for threatened species. IWRB's Wetland Division coordinates activities through a wetland management group. Activities include the compilation of regional wetland inventories, the preparation and implementation of management plans, the publication of wetland management handbooks, and the organization of waterfowl and wetland workshops and training courses.

In Bangladesh, IWRB initiated the annual waterfowl count program (responsibility for the count in Asian countries was shifted to AWB in 1992), which includes sites in the Northeast Region.

Asian Wetland Bureau. AWB, founded in 1983, is an independent non-profit organization dedicated to promoting the protection and sustainable utilization of wetland resources in Asia. The headquarters office is located in Kuala Lumpur, Malaysia; Indonesia, the Philippines, and India have national offices. Funding sources for conservation activities include contributions from international environmental NGOs, revenues from environmental consulting, and private contributions. AWB works in four specific areas: biological diversity; water resources; institutional strengthening and public awareness; and environmental management and policy. Its activities include organizing wetland study and management courses and scientific symposia, and publishing reports and a twice-yearly newsletter (*Asian Wetland News*).

In Bangladesh, AWB has (since 1992) responsibility for the annual International Waterfowl Count, in cooperation with IWRB. AWB has provided consultants to some development projects (Forestry III project appraisal/World Bank, NERP), and has participated in the annual Flood Action Plan conferences. AWB will likely merge with IWRB.

National academic institutions and NGOs
This section describes:

- NACOM, the NGO that undertook the NERP environmental studies (extensive wetland fieldwork plus support of the surface water quality mission) and is expected to provide much of the national staff for NEMREP fieldwork;
- PRISM, the NGO that has pioneered duckweed aquaculture/wastewater treatment in Bangladesh;
- Several NGO/private sector entities of particular relevance to NEMREP; and

- Relevant activities at Shahjalal University of Science and Technology, Sylhet, the leading academic institution in the region.

Again, other organizations that could not be mentioned here have also made and will continue to make valuable contributions to development generally in the region, and to biodiversity conservation in particular.

Nature Conservation Movement. NACOM, formally established in 1987, concerns itself with nature conservation and field research, focusing mainly on wetland ecosystems, with special emphasis on herpetology. The organization has been involved in a variety of projects across the country, including:

- Teknaf peninsula wild elephant population management plan (WWF);
- Wildlife surveys — of Hispid Hare and Pygmy Hog (IUCN/SSC), Monitor Lizard (IUCN/WTMC), Sarus Crane (ICF), Otter (WWF), Estuarine River Terrapin (WWF), Freshwater turtle trade monitoring ("Care for the Wild" and University of Kent DICE), Padma River Gharials
- Marine turtle nesting beach surveys; turtle egg artificial hatching experiments, involving local people nest and egg protection (NACOM/Forest Department Joint Venture)
- Coastal wetland assessment — with Asian Wetland Bureau, as part of World Bank Forestry III project appraisal
- NERP wetland studies
- Three rural Nature Conservation Centres at Whykeong, Cox's Bazaar District, Kapasia, Gazipur District, and Sardarpara, Munshiganj District, involving local people fully in operation and management and emphasizing non-formal education (Nagao Environmental Foundation, Japan; BRAC),

PRISM Bangladesh. "Prior to 1988, duckweed had been used only in commercial applications to treat wastewater in North America. In 1989, staff of a non-governmental organization based in Columbia, Maryland, The PRISM Group, initiated a pilot project in Bangladesh to develop farming systems for duckweed" (Skillicorn, 1993, p. vii). PRISM Bangladesh was created out of this pilot project and is now involved in extending the duckweed aquaculture model.

Bangladesh Chemical Society. BCS was first organized in 1972 as a learned society, then was expanded to include industry, government, and other establishments. "The society has achieved a truly national character", and has seven regional committees, including one in Fenchuganj and one in Sylhet (BCS, 1993).

It is "dedicated to improve the quality of chemical education and research, industrial and technological output and overall well being of chemists and chemical technologists in Bangladesh. . . . For the last several years, BCS has actively pursued various nation-building activities particularly in the fields of education, research, and industrial development. These activities have established BCS as the leading learned and professional body of the country."

The organization has numerous aims; two of particular relevance to NEMREP are: "to organise conferences, seminars and symposia, lectures and workshops on problems of national and professional interest"; and "to cooperate with various governmental and non-governmental

agencies, departments, chemical and pharmaceutical industries and offer advice and consultancy services".

BCS has organized several workshops on environmental topics. At the most recent annual meeting (the sixteenth), one of the three technical sessions was devoted to "industrial chemistry, chemical technology, and environmental chemistry" (BCS, 1993).

Private laboratories with water quality testing capabilities. A number of laboratories in the country perform water quality testing of one sort or another. These would include labs at DOE; Bangladesh University of Engineering Technology; International Centre for Diarrhoeal Disease Research, Bangladesh; PRISM; and Bangladesh Atomic Energy Commission. There are certainly others. Hach kits have been used here under FAP 16.

Existing environment NGOs and NGO fora as models for NEMREC. A number of existing environment NGOs in Bangladesh, leading environment NGOs in the region (such as Haribon in the Phillipines, which now has close working agreements with government to achieve national environmental objectives), and NGO fora (such as ADAB) provide potential models for how NEMREC should be structured. It would be highly useful to study a selection of these for lessons learned before designing NEMREC.

Shahjalal University of Science and Technology, Sylhet. There is an Environment Committee at the University which has expressed an interest in increasing university involvement in regional environmental concerns, including water quality monitoring, fisheries management, and afforestation. The proposed Biology Department currently under consideration by the academic council may also afford an opportunity for an emphasis on locally relevant environmental issues in the new faculty positions, courses, and research activities that this would entail.

2.3.4 Government/NGO links

One of the recommendations of the 1991 Karachi meeting (see IUCN activities above) was that the Government should designate a Wetland Committee that would include representatives of a wide range of interested parties from inside and outside government. Since that time, a group of environmental NGOs met with the Secretary, MOEF, for discussions, but the group has not been institutionalized.

It is now usual at national (FAP), regional (SAARC), and international (Rio) meetings for NGOs to convene parallel meetings and forward their recommendations to the governmental sessions. Also, Audubon (U.S. non-profit conservation organization) has been designated by a group of international environmental NGOs, to monitor and disseminate information about the Flood Action Plan, with the aim of influencing donor governments, particularly in Europe.

2.3.5 Foreign academic institutions and conservation action groups

Worldwide, actual expertise in habitat restoration and species recovery is concentrated in academic institutions and conservation groups in both industrialized countries and in developing countries that have taken particular interest in conservation. A few examples will suffice to illustrate.

The Durrell Institute of Conservation Ecology (DICE) at the University of Kent (UK) is a leading institution worldwide addressing biodiversity conservation. A number of Bangladeshi students

and investigators have gone through their graduate program, or undertaken research in collaboration with their investigators. The Smithsonian Institution (US) and the Conservation Research Center (US) assisted the Government of Malaysia to restore habitat for and re-establish a population of rhinoceros; this program was discussed at the Smithsonian/GOM International Workshop on Wildlife and Park Management held in Kuala Lumpur in 1988, in which one Bangladeshi participated. The Ministry of Environment of India has also re-established habitat and populations of rhinoceros near Madras.

Numerous Canadian researchers are involved in habitat and species recovery research and implementation. NERP/NACOM has identified and contacted individuals in the area of raptor and reptile recovery, and has received encouraging replies indicating both impressive qualifications and a high degree of interest. The Canadian group Ducks Unlimited, whom we have not yet contacted, has a great deal of experience in habitat conservation focusing on waterfowl.

These institutions and individuals can be a key resource to NEMREP implementation, as well as contributing to institutional development objectives less directly. The NERP Environment Team has learned a number of lessons in this area, however:

- Identifying, contacting, negotiating with, and scheduling academic researchers and conservation groups can be a lengthy process, and lead time should be allowed for this.
- Committed donor-country project office support in this process is essential. Networking exclusively from a base in Bangladesh is slower and less effective.
- Donor (e.g. CIDA) citizenship restrictions on project consultants and contracts are a key constraint.
- Flexibility in contracting and funding is key. Hiring academic researchers as project consultants (the conventional route) should be augmented by the flexibility to fund:
  - Bangladeshi students/post-docs/professors' tuition and expenses at foreign institutions, for coursework and research linked to NEMREP-related field work in Bangladesh;
  - Costs of NEMREP-related field research in Bangladesh by donor country (Canadian) graduate students;
  - Study tours to visit ongoing habitat restoration and species recovery projects in the region and in the donor country;
  - Activities necessary to the development of new individual and organizational partnerships between Bangladesh NGOs/universities and donor country institutions
  - Attendance at regional and international symposia and conferences dealing with biodiversity conservation in general, and with wetland, threatened community, and threatened species conservation and management in particular

  Also, given the wide range of extremely specialized inputs required, implementation will be much less effective if staffing decisions are unduly constrained by restrictions on or financial disincentives to contracting firms in subcontracting independent consultants or firms rather than their own permanent staff.

2.3.6 Donor agency involvement

Numerous donor agency environmental reviews were prepared in the late 1980s and 1990s. The more recent ones each note the special significance of the wetlands of the Northeast Region (Dean

and Treygo for CIDA, 1989, p. 39; World Resources Institute for USAID, 1990, p. 25; and World Bank, 1991, pp. ix and 34-35), whereas the older ones do not (ADB, 1987; Barker for UNDP, 1988; DANIDA, 1988).

Table 2.4 indicates which donors are supporting projects and programmes of relevance to the region's wetlands.[2]

In the past donors have provided small amounts of support for numerous relatively small-scale environment activities undertaken both by GOB and NGOs. An example would be German Cultural Institute support for the *First International Seminar cum Workshop for Conservation of Wildlife in Bangladesh* which was held in Dhaka on 1-4 December 1986.

2.3.7 Projects and programmes

Current, future, and proposed projects and programmes in and affecting the wetlands of the Northeast Region other than water resources projects are listed briefly in Table 2.4. Additional information on the Asian Waterfowl Count and on Bangladeshi investigators active in the region is given below.

Existing water resources projects are documented in the *Regional Water Resources Development Status* (NERP, 1992). Proposed water resources projects are documented in the NERP regional plan, and in pre-feasibility studies. These studies document potential impacts of proposed projects on natural biological systems, in particular the key wetland sites and threatened communities and species.

Annual Waterfowl Count. Since 1987, an international waterfowl count is organized by IWRB in January every year, and count data has been submitted by Bangladesh every year since that time. Six sites in the Northeast Region were included for the last two years. Once a new site is established, it is visited every year thereafter to allow longitudinal studies.

Private investigators. A number of private investigators from academia and NGOs are receiving funding for biophysical and ethnobiological studies in the wetlands and the uplands of the region. NERP is aware of some of these activities but has not prepared a comprehensive list.

2.4 RATIONALE

2.4.1 Introduction

The purpose of this section is to discuss why this project is deserving of priority attention. Opportunities and constraints are discussed. The approaches taken are discussed, and the technical, social, and economic reasons for choosing these in preference to others are presented. The scope and scale of the project is discussed (Gittinger, 1982, p. 414).

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[2]NERP has not compiled a comparable list of water quality management projects. NERP has learned, however, that the recently mobilized National Minor Irrigation Development Project will be designing a national ground water quality monitoring system, with adjunctive monitoring of surface water quality, and ecological and public health indicators linked to water quality (possibly e.g. aquatic flora and fauna including fish and so on).

Table 2.4: Projects and programmes of relevance to wetlands of the northeast

Name	Department	Time	Cost	Donor	Relevance
Development of Cane, Bamboo, and Murta Plantation	Forest	1992-5	Tk 54 million	ADB, UNDP	Wetland plantation of murta
Development of Conservation and Management of Wildlife	Forest	1992-5	Tk 100 million	ADB, UNDP	Major wetland wildlife component
Survey of Endangered Wildlife of Bangladesh	Forest	proposed Feb 1991	USD 0.44 M	proposed to Japan, USA, IUCN	Wetland wildlife component
Strengthening of Bangladesh National Herbarium	Forest			ODA	Upgrade floral research and conservation facilities
Management of Wetlands and Conservation of Biodiversity in Bangladesh	Environment	project concept paper Mar 1992	USD 2.5 million (first two years only)	proposed for GEF funding	Develop/implement management plan for important inland wetlands to conserve biodiversity
Environment Study, Flood Action Plan 16	Flood Plan Coordination Office	1991-1993		USAID	Take wetland values into account in EIA guidelines for water projects; special studies of selected wetland values
Forest Resources Management Project	Forest	1992-1999	USD 63 million	World Bank	Wildlife management
Forestry Master Plan	Forest	1991-3	USD 1.9 million	ADB, UNDP, FAO	Fundamental sectoral policy and organizational changes
Second Aquaculture Development Project	Fisheries	1992-5	Tk 990 million	ADB	Floodplain stocking; wetland wildlife impacts

2.4.2 Future without-project scenario

The initiatives presented here are urgent primarily because they may avert several highly adverse outcomes otherwise expected over the coming decades:

- The ecological character of most or all of the nine key wetland sites could be seriously degraded, and the values relating to their international significance lost;
- Each of the three threatened ecological communities would in all likelihood be eradicated;
- The region's remaining semi-natural mixed forest would disappear;

- The foregoing systemic changes would cause the regional extinction of numerous species, and would contribute significantly to the risk of permanent, global extinction of some of these;

- The total tangible and intangible benefit stream emanating from the key wetland and threatened community sites will continue to be driven to lower and lower levels, with serious negative effects on the well-being of local communities;

- Industrial and urban domestic pollution will intensify greatly, and will be accompanied by tremendous social, ecological, and economic costs — tangible and intangible;

- The gap between resources and the need for action on biodiversity and surface water quality management will widen dramatically; the limited public and private resources available will be deployed in an ineffective and fragmented fashion; and

- The lack of appropriate regional and national fora for discussion among stakeholders and for the participation of local people will preclude development and cooperative implementation of consensus solutions.

2.4.3 Project packaging

The eleven initiatives were packaged together as a single project for several reasons. First, the eleven initiatives have many important biophysical and institutional linkages and synergies. Second, individually, most are very small, but collectively have critical mass in biophysical and institutional terms. Third, combining them in a single project would be cost-effective in that many of the technical inputs could be used to better advantage, and supervision/monitoring by the executing agency and donor would be more efficient.

Alternative packaging would be either: (1) a *Surface Water Quality Project* and a *Biodiversity Project*, or (2) same, but with *Pulp and Paper Mill Effluent Treatment* extracted and done as a third stand-alone project. Further investigation and discussion will be needed to determine fully the pros and cons of these approaches.

2.4.4 Geographical scope

The geographical scope of NEMREP is the Northeast Region, as defined for the Flood Action Plan. We believe a regional rather than national project will have several definite strengths. First, a regional project, in having to address only one-fifth of the country, will be smaller and more manageable. Second, the regional scope will help to keep attention on a set of strategically important field sites; this approach is complementary to past and ongoing national-level, desk-bound, top-down conservation projects, such as the *National Conservation Strategy* and the *National Environment Management Action Plan*. Third, a regional project could be the first in a set of regional projects to cover the whole country; this would allow for methods tested in the earlier projects to be replicated, with necessary improvements, in the later ones. Finally, a regional project supports bottom-up planning, by facilitating the generation of information and experience at field level and its movement upwards into national policies and plans.

The regional nature of NEMREP cannot, of course, erase the reality that environmental processes and concerns extend beyond administrative and political boundaries within and between countries. That fact expresses itself in many ways throughout this report.

2.4.5 Surface water quality management rationale

Clean water is basic to quality of life, public health, to most economic activities, and to proper functioning of natural biological systems. The challenge is to develop means for surface water quality management that are cost-effective and appropriately targeted to specific end users' needs, embracing both proactive measures to prevent new pollution problems from developing and remedial measures to deal with existing problems.

Surface water quality characterization

Decisions about water quality management must be based on adequate information. Too often, however, water quality monitoring programmes are designed and carried out without adequate involvement of the persons and agencies who must make actual water quality management decisions (policy makers, development and city planners, public health, sanitation, and pollution control officials, local communities). Such monitoring programmes appear to 'work', in that technicians following the agreed-upon procedures may produce many years of data, but without ever contributing anything to improved water quality, improved water quality management planning, or cost savings in achieving particular water management objectives.

NEMREP surface water quality management activities emphasize ongoing involvement of and feedback from decision makers themselves — local communities as much as central government regulators. The intent is to tie water quality characterization activities as much as possible to water quality management decisions and actions, and to use the characterization exercise to bring various interested parties together for education and discussion. Within this context, acceptable water quality standards should be agreed among interested parties on a case-by-case basis and management strategies particularized to each situation, rather than trying (and usually failing) to achieve uniform compliance to national water quality standards which have, in effect, been lifted piecemeal from other countries' standards.

On the technical side, field methods of chemical analysis are emphasized. This approach increases staff productivity and motivation while reducing costs, allows for on-the-spot evaluation of sample sites, and improves accuracy.

Industrial pollution abatement

The Northeast Region, while less industrialized than other parts of Bangladesh, does have its share of industrial pollution sources, and regional industrial pollution is likely to double over the next decade. An estimate for the number of industrial pollution sources in the region would be about 300, estimating from the region's population share and relative industrialization and the 1991 DOE finding of over 2000 industrial pollution sources nationally[3]. Nationally, the industrial base has been growing by 5.7% annually and under current policies is targeted to grow by 9-10% per year (*Interim Report*, NERP 1992). At the same time, the region is urbanizing at what will be its fastest-ever rate, bringing greater and greater numbers of people into areas most susceptible to industrial pollution. The region's single most important single source of industrial pollution is the Sylhet Pulp and Paper Mill, which is blamed for significant fish kills and contamination and local public health problems.

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[3]In a 1991 DOE national survey, over 6000 industries were surveyed and over 2000 industrial pollution sources were found. These were broken out by pollution rates: >600 facilities were classified as 'very high', >800 as 'medium', and >600 as 'low'.

Industrial pollution problems in Bangladesh and particularly in the Northeast Region are still minor compared to other Asian countries. This should not be seen as a reason for complacency, but rather as an opportunity for the region to act now to 'skip' the industrial pollution problems that are now being experience elsewhere. Action taken now to manage new sources of pollution will pay for itself many times over in terms of improved public and occupational health, fisheries productivity, higher growth and lower costs for business and other activities dependent on clean water and air, lower environmental clean up and abatement retrofit costs, and so on.

The utility of conventional industrial pollution control means (enforcement of standards, tradeable pollution credits, and so on) will continue for the foreseeable future to be constrained by weaknesses in the institutional environment in Bangladesh. Thus, as much as possible, the focus in NEMREP is on motivating and providing information and technical assistance directly to industry, both public (BCIC) and private (industrial firms, developers, lenders/investors, and the chemistry/chemical engineering profession).

A key assumption, of course, is that means can be found to induce industrial interests to respond favourably (i.e. spend money on pollution abatement), in the absence of actual legal compulsion. While this may seem unrealistic, businesses have many interests beyond simple legal rectitude:

- Reputation: gain favourable publicity, avoid adverse publicity, establish/maintain good community relations
- Risk aversion: willing to incur small up-front costs, relative to clean-up or retrofit costs, to reduce risk exposure. Risks relate mainly to future legal action to enforce existing or new pollution control laws, or legal suits for pollution-caused personal or property damages.
- Productivity: ensure safety and health of workers, protect facilities from pollution-related damage.

Application of aquatic treatment methods to rural and urban domestic wastes

The floating aquatic plants with the greatest known potential for wastewater treatment include water hyacinths, duckweeds, pennywort, and water ferns.

Water hyacinth systems are capable of removing high levels of biochemical oxygen demand (BOD), suspended solids (SS), metals and nitrogen, and removing a significant level of trace elements. Hyacinths on the water surface of a pond create a totally different environmental condition in the water as compared to an exposed water surface. The dense canopy of leaves shades the surface and prevents algal growth. The near surface water tends to be low in oxygen and the benthic zone is usually anaerobic even in shallow ponds.

Duckweed systems are capable of removing a high level of BOD and SS, and removing a significant level of metal and nutrients. As compared to hyacinths, the duckweed plants play a less direct role in treatment due to their small size. The lack of an extensive root zone provides very little substrate for attached microbial growth. The growing plants will form a single layer completely covering the water surface, then some species will grow on top of others leading to the formation of a thick mat. The formation of this mat is probably the most significant contribution of the duckweed plant to wastewater treatment. The surface cover prevents algae growth, stabilizes pH, and enhances sedimentation but is also likely to result in anaerobic conditions due to the relatively low photosynthetic oxygen production from the small plants.

The use of submerged aquatic macrophytes for treatment of wastewater has been tested in the laboratory and greenhouse and in a pilot scale field study in Michigan. The units with *Elodea nuttalli* did demonstrate a significant removal of BOD, phosphorus, and nitrogen. The performance of these units was slightly better than the control units that contained no plants. The other plant species that were tested (*Myriophyllum heterophyllum, Ceratophyllum demersum)* were rapidly fouled with filamentous algae which in turn reduced productivity and system performance.

Natural Systems for Waste Management & Treatment by Sherwood C. Reed, E. Joe Middlerbrooks and Ronald W. Crites (McGraw Hill, New York, 1988) contain information on the use of aquatic plants in wastewater treatment. Information from these publications is presented in Annex C.

Duckweed has been used in Bangladesh for the treatment of waste water while generating employment and cash income through the production of valuable protein-rich biomass usable locally as fish feed. Both a centralized treatment facility for a community of 25,000 and a number of pond-based systems at the village level have been implemented in Bangladesh by the NGO PRISM. The PRISM program is documented in a World Bank publication (Skillicorn et al., 1993).

A first step towards achieving acceptable treatment of regional urban domestic wastes and employment and economic benefits from aquatic plant treatment systems would be to undertake feasibility studies for the largest urban areas of the Northeast (Sylhet, Narsingdi, Bhairab, Kishoreganj, Sherpur, Netrakona, Habiganj, and Moulvibazar; NERP Study on Urbanization, 1993). The total projected 2015 population of these cities is 1.6 million. Feasibility studies would need to emphasize local consultation with regard to institutional arrangements (e.g. public-private joint venture), siting, and local resource mobilization.

In-depth investigations of the prospects of using water hyacinth for wastewater treatment should be an integral part of the feasibility study.

An additional 7.4 million persons will live in urban areas with populations larger than 20,000 in 2015. Feasibility studies of aquatic treatment systems for a representative selection of these smaller urban areas should also be carried out.

Intervention principles

The principles guiding the design of the proposed surface water quality management interventions are:

- Establish acceptability of effluents and of water quality in the variety of regional waters on a case-by-case basis, reflecting input from local residents, Government, technical experts, and facility owners. Dictating standards from above, without any flexibility to reflect biophysical, social, economic, and political circumstances of specific settings is counterproductive (no pollution abatement is done).

- Seek out the best technology available for wastewater treatment and for data collection, for each application and facilitate rapid adoption. 'Best' would include high cost-efficiency (both initial investment and redundant costs), low foreign content (in equipment, equipment maintenance, and in initial and ongoing staff inputs), acceptable performance (on

acceptability, see above). Two examples of promising technologies include field-based chemical analysis equipment (e.g. Hach kit) and aquatic wastewater treatment.

- Prioritize and rationalize wastewater treatment and data collection activities very carefully. This is key, as resources for water quality management are limited.

- Increase public-private and NGO-private cooperation, and local participation greatly. Examples would include programmes to work with smaller industries to reduce emissions through simple, low cost measures; working with chemists as a professional group through the Bangladesh Chemical Society; and public consultation regarding acceptability as mentioned above.

- Reduce pollution discharges at Sylhet Pulp and Paper Mill, the existing major industrial polluter in the region, to acceptable levels. This would be of clear public benefit, and public funding at some level would be appropriate. Also, the donor community should fund all or part of the clean up, since this facility was constructed with donor assistance.

- Create a sustainable ongoing water quality characterization capability able to respond directly to decision-makers' information needs. These needs would include: tracking trends in water quality, understanding the impacts and relative importance of existing pollution sources, monitoring compliance with effluent and water quality standards, identifying public health hazards; and so on.

2.4.6 Biodiversity initiatives rationale

Locally-based management of internationally significant wetland sites

Freshwater wetland biodiversity of Bangladesh, which was once characteristic of much the nation's area, is concentrated now in the Northeast Region which contains all of the nation's remaining large semi-natural freshwater wetlands (Directory of Asian Wetlands, 1989). Logically, then, efforts to preserve this important aspect of the nation's natural heritage should focus on the Northeast Region. The Government of Bangladesh's commitment to wetland conservation and improved management was expressed by its accession in 1992 to the Ramsar Convention, the main international agreement addressing wetland conservation and improved management.

Given that resources are limited, efforts should focus on the nine key wetland sites (see map, Figure 2) which have been identified as meeting one or more Ramsar Convention criteria for international significance (Table 2.2). The emphasis should be on locally-based management, with project input consisting of assistance to local residents to design and implement management plans that enhance both biodiversity values and sustainable benefits to local people. This approach mobilizes local resources and minimizes central government dependency and reduces conflicts between conservation and utilization objectives.

Threatened and economically/ecologically valuable communities — need for improved management and habitat restoration

Lowland forest, reed lands, and floodplain grassland are key elements of lowland biodiversity. All three are threatened as ecological communities. In addition, these resource systems provide direct economic and other benefits to local people; enhance openwater fishery and wildlife habitat

and fishery productivity; protect homesteads from wave erosion; improve water quality; and stabilize land use.

The thrust of the interventions recommended here is to use appropriate locally-based methodologies rapidly to re-establish these communities over suitable area, and to achieve sustainable management.

Threatened and commercially threatened lowland animal and plant species — recovery and possible reintroduction plans

Biodiversity at the species level logically focuses first on globally threatened and commercially threatened plant and animal species. Action is urgently needed to prevent the loss of extant regional populations of these species and thereby an increase in their global vulnerability. Re-introduction of regionally extinct species would reduce vulnerability of these species; this could only proceed after careful evaluation in terms of the potential ecological, societal, and economic benefits and costs, however.

Upland biodiversity conservation

The remaining natural and semi-natural upland forests of the region and immediately outside it in India are known to be important biodiversity havens (Haroun er Rashid, pers. comm.). Their biodiversity deserves special attention in its own right, and also in terms of migratory and other linkages to lowland areas.

Intervention principles

The principles guiding the proposed biodiversity interventions are:

- Target interventions carefully to the most valuable and most threatened biodiversity elements. Lowland biodiversity, and opportunities to preserve it, are not distributed uniformly throughout the region; some ecological communities and species are threatened, others are thriving; threats are typically very specific in their actions; some villages depend heavily on wetland resource gathering, others do not; some threats occur within a narrow time window. The challenge is to zero in on where, how, when, with whom, and on behalf of which biological system or species to intervene.

- Require win-win outcomes (rehabilitated forest provides habitat for wildlife and provides economic benefits to local residents). Biodiversity conservation options to the detriment of human welfare will not be viable. It is recognized that not all species can exist in a system that is managed for economically valuable products, such species are better protected in parks, ecological reserves, and the like, where systems are protected from harvest-related disturbance for their own intrinsic (or ecotourism) value.

- Interventions should help to make nonconsumptive and consumptive use of wild species more sustainable. The IUCN/SSC Specialist Group on Sustainable Use of Wild Species provides guidance in this area e.g. draft final guidelines will be submitted to the IUCN General Assembly in January 1994 (IUCN, 1993a).

- Empower local people to be the main agents for biodiversity preservation and wetland resource/forest resource management. The proper role for outside parties with an interest in these matters — and this would include game law enforcement personnel, Forest

Department field staff, environment NGOs, research scientists, and so on — is to support local communities, through informal training, group formation, technical assistance and funding for locally-based conservation projects, and other measures.

- Establish, implement, monitor, and evaluate site management plans and species recovery plans on a site-by-site, species-by-species basis, reflecting input from local residents, Government, technical experts, landowners, and other interested parties.

- Collaborate closely with established species recovery programs and species recovery scientists in other countries.

- Recognize that biodiversity conservation represents a public benefit that transcends national boundaries; external funding is appropriate.

2.4.7 Institutional development initiatives rationale

National institutional development
The recent strengthening of national policies regarding surface water quality and biodiversity awaits commensurate national institutional development. In addition, overarching national policies regarding public participation, self-reliance, and so on, need to be incorporated in all national institutions, including those in these two areas.

Strategic planning at the highest level is needed to identify and develop appropriate programmes in the areas of surface water quality and biodiversity for the necessary key changes in legislation, agency mandate and regulations, staffing and staff training, inter-agency cooperation mechanisms, arrangements for public participation, and so on. In preparation for the planning exercise, there is a need for staff development activities to heighten awareness of surface water quality issues, treatment technologies, and so on, and of the value of biodiversity components.

Creation of a regional environmental institution
Improved surface water quality management and biodiversity conservation will not be achieved by unilateral central government action, nor by direct partnership between local people and central government bureaucrats. There is a need for institutional development at intermediate levels. Regional level institutions are ideally suited to fill this gap, with scale and competence to command national attention, while having a primary orientation towards the needs and views of residents and communities in the region.

Such a regional institution would also provide assistance in mobilizing local and regional input to environmental planning, assessment, and management of development projects.

Intervention principles
The principles guiding the proposed institutional development interventions are:

- A key objective of institutional development is to move toward sustainable systems — biophysical, social, financial, institutional.

- All interested parties (stakeholders) should be involved in institutional development activities, in keeping with the shift in emphasis from top-down to participatory planning.

- Appropriate involvement of all stakeholders is an ambitious and innovative objective. Ample time and resources must be allowed to identify and communicate stakeholders, and to devise communication channels and fora that facilitate productive consultation.

- The NERP strategic planning process can be used as a starting point for devising strategic planning procedures in biodiversity and surface water planning. Adaptation will be needed.

- NEMREC should reflect the needs and wishes of stakeholders, including and in particular local communities, in regional biodiversity and surface water quality management. The challenge will be to devise an organizational structure with, among other things, a workable division of power and control between directors (stakeholder representatives) and NEMREC management. Existing Bangladesh 'meta-NGOs' such as ADAB, which are controlled by a group of member NGOs and other entities, should be examined. Foreign and international conservation organizations of this type may also provide useful prototypes; one such would be a secretariat-type arrangement. It is believed that a workable structure can be developed within the laws and regulations that define and govern NGOs in Bangladesh.

3. PROJECT OVERVIEW

3.1 INTRODUCTION

This chapter presents the project goal; purpose; objectives; structure; cost estimates; and phasing. Detailed descriptions of each project work package are provided in Chapter 6.

3.2 GOAL

The overall goal addressed by the Project is to improve environmental quality in the Northeast Region, within the context of sustainable development and social improvement.

3.3 PURPOSE

The project purpose is:

- To improve surface water quality management
- To safeguard the region's remaining biodiversity for future generations, emphasizing enhanced sustainable exploitation of natural systems for the benefit of the local poor
- To assist national institutions to improve their capabilities in the areas of surface water quality management and biodiversity conservation
- To help to establish a sustainable regional institution dedicated to regional environmental management, research, and education, which would carry forward the interventions initiated under NEMREP

3.4 OBJECTIVES

3.4.1 Surface water quality

Overall: **To support improved regional surface water quality management.**

Specific:

- Reduce to acceptable levels industrial pollution from key polluters in the region (in practice this is Sylhet Pulp and Paper Mill; Fenchuganj fertilizer factory is now closed)
- Characterize regional water quality and pollution sources as needed for informed decision-making

- Support the use of aquatic technologies for rural and urban domestic wastewater treatment

- Improve awareness and implementation of good industrial housekeeping, pollution prevention including 'clean technology, and basic treatment technologies, among owners, managers, and personnel of existing and new industrial facilities

3.4.2 Biodiversity

Overall: **To safeguard the region's remaining lowland biodiversity for future generations.**

1. *General:* To stabilize the ecological character of the nine most important remaining semi-natural wetland sites (Tangua Haor; Pasua Beel, Gurmar Haor; Hakaluki Haor; Hail Haor; Balai Haor; Kawadighi Haor; Bara Haor; Khaliajuri Area; Companiganj Area) for the benefit of local people, openwater fishery production, and regional biodiversity.

   Specific: Objectives for each site will need to be formulated based on consultations among local people, technical experts, landowners (principally GOB), and government.

2. *General:* To rehabilitate, extend, and sustainably manage swamp forest, floodplain grassland, and reed swamp habitats, three lowland communities once characteristic of the region that have all but disappeared. The potential biological and economic productivity of these lowland resource systems would benefit local people, enhance openwater fishery habitat and productivity, protect homesteads from wave erosion, improve water quality, and stabilize land use, as well as playing an important role in regional biodiversity.

   Specific - swamp forest: A halt to felling, decapitation, and over-coppicing of mature trees; social afforestation on all ecologically and socially suitable area (yet to be identified), relying principally on natural regeneration under local protection. Sustainable social management of afforested areas.

   Specific - floodplain grassland: Preserve existing floodplain grassland areas, and restore this habitat in any other areas found to be suitable.

   Specific - reeds: Social afforestation and sustainable social management of 19,000 ha of unencroached Forest Department reed land, plus suitable areas (yet to be identified) under other ownership.

3. *General:* To ensure the survival of viable populations of extant upland and lowland animal and plant species. To investigate criteria and methods for re-establishing regional extinct species.

   Specific: Objectives must be formulated for each species. These should be based on consultations among local people, technical experts, landowners (principally GOB), and government.

3.4.3 Institutional development

Overall: **To develop and strengthen regional and national institutional elements in support of sustained surface water quality management and regional lowland biodiversity conservation.**

1. *General:* To support national institutional development in the areas of surface water quality management and biodiversity conservation.

   Specific: To address strategic concerns in the areas of *inter alia* national policies and legislation; agency organization, professional staff development, and regulations; inter-agency cooperation agreements and structures, and public/private partnership, as these relate to surface water quality and biodiversity, through technical assistance, training, support for conferences, and similar means.

2. *General:* To create a regional institution capable of addressing biodiversity, surface water quality, and related concerns; which is sustainable, transparent, and efficient, responsive to changing opportunities and threats, and has proper accountability.

   Specific: To establish an autonomous regional environmental non-governmental organization with the technical and community organization capabilities needed for ongoing support to a broad range of ongoing and self-initiated actions in environmental management, research, and education, in particular as these relate to lowland biodiversity and surface water quality. Ongoing actions would include those identified previously under the lowland biodiversity and surface water quality objectives.

3.5 SUMMARY DESCRIPTION

The project aims to benefit local communities, the nation, and the international community through measures to improve biodiversity conservation and surface water quality management, and to strengthen the overall institutional framework in these areas. The project focuses closely on specific issues, sites, and landscape elements identified through the NERP strategic planning process as of the greatest importance.

The project approach is to allow problems and solutions to be defined in dialogue with and among all interested parties (stakeholders). These include foreign and Bangladeshi technical experts, representatives of government and non-government agencies, private entrepreneurs and companies, and local communities.

The project would promote solutions that can be implemented, monitored, and evaluated for the benefit and through the agency of local people and institutions as much as possible, with other entities playing a supporting role. Key words associated with this type of approach are decentralization, privatization, public-private partnership, locally-based management, and extensive consultation.

Criteria for evaluating proposed measures and their impacts would also be developed through the consultation process. Among other things, certain concepts already known to be key would have

to be addressed: technical and economic feasibility; and biophysical, social, financial, and institutional acceptability and sustainability. Acceptability could involve *inter alia* environmental management measures for any localized adverse impacts.

On the institutional side, the project would provide opportunities for interested parties (as defined above) to undertake strategic planning exercises in biodiversity conservation and surface water quality management at the national level, modelled on the NERP regional plan methodology, and closely tied to ongoing NEMREP field-based work. NEMREP would also support the creation of a decentralized, private-sector (NGO) regional environmental centre. This was identified during the NERP strategic planning as a key mechanism to increase local involvement and to improve public-private partnership.

In general terms, project outputs will consist of reports documenting field investigations, consultation, problem and solution definition, monitoring and evaluation, and so on; improved biophysical status of sites, ecological communities, and species; baseline data and accompanying analysis of regional surface water quality; feasibility study and construction of pollution abatement facilities at the Sylhet Pulp and Paper Mill; feasibility studies of aquatic wastewater systems and construction (through private companies with private credit) of several systems; and national strategic plans for biodiversity conservation and surface quality management.

Project inputs will consist of (in order by magnitude): human resources and related costs; funds for the construction of the SPPM pollution abatement infrastructure; office and field equipment (computers, furniture, water quality monitoring equipment, and so on); and funds for non-personnel costs associated with institutional development activities (travel allowances, copying, and so on).

The only potential adverse project environmental impacts that can be foreseen now, are localized land use changes and consequent secondary impacts, at specific sites used for biodiversity and surface water management activities, and it is anticipated that these can be managed acceptably through conventional means (mitigation, compensation, etc.).

The main assumptions for success of the project are that:

- GOB and the donor government will remain committed to the objectives of the project;
- Biodiversity conservation measures can be defined and implemented which are mainly locally-based, and biophysically, socially, and economically feasible;
- Project measures are adequate, relative to other pressures (including in particular other development activities and projects), that biodiversity assets can be stabilized before disappearing altogether from the region or the globe; and
- Positive synergies can be achieved, between and among international and national scientists/academics, NGO/conservation groups, government agencies, and local people.

3.6 WORK BREAKDOWN STRUCTURE

A work breakdown structure for the project is shown in Figures 3 and 4.

3.7 COST ESTIMATES

A breakdown of capital costs by component and by source (public/private) is shown in Table 3.1. Total capital costs are US$ 39.6 million. Of this, public costs account for US$ 9.6 million and private costs for US$ 10 million. The estimate of private costs assumes that over the five years of the project duckweed wastewater treatment/aquaculture fish food systems would be privately implemented in several of the eight major urban centres and a few smaller towns. There will likely be a need to arrange credit facilities to finance the private costs.

A number of project elements will or could incur public or private recurrent costs. These can be estimated only for the SPPM pollution abatement, for which public recurrent costs would be US$ 50,000$\pm$20,000 annually.

3.8 PHASING

Five years are required to implement the project (Figure 5). Beyond this time frame, it is assumed that this project would spin off additional projects or phases to address ongoing and newly-identified concerns.

Table 3.1: Capital costs

BIODIVERSITY	
Key Wetland Sites	US$ 2.0 million
Threatened Ecological Communities	1.7 million
Swamp forest 0.7 million	
Floodplain grassland 0.3 million	
Reed swamp 0.7 million	
Threatened and Commercially Threatened Species	0.6 million
Species experts 0.3 million	
Pilot farms 0.3 million	
SURFACE WATER QUALITY MANAGEMENT	
Regional Water Quality Characterization	0.7 million
Pulp and Paper Mill Effluent Treatment	2.0 million
Feasibility study 0.2 million	
Implementation 1.8 million	
Industrial Pollution Abatement at Smaller Facilities	0.3 million
Aquatic Plant Domestic Waste Treatment	11.0 million
Feasibility Studies & Related 1.0 million	
Implementation (private cost) 10.0 million	
INSTITUTIONAL DEVELOPMENT	
Biodiversity Strategic Planning Exercise	0.3 million
Surface Water Quality Management Strategic Planning Exercise	0.3 million
NEMREC	0.7 million
Set up 0.5 million	
Transitional funding 0.2 million	
TOTAL PUBLIC COST	**9.6 million**
TOTAL PRIVATE COST	**10.0 million**
GRAND TOTAL	**US$ 19.6 million**

4. ORGANIZATION AND MANAGEMENT

4.1 ORGANIZATIONAL STRUCTURE

The Project will be implemented jointly by (Figure 6):

- Ministry of Environment and Forests
- Executing Agency (EA)
- Local groups organized under the project
- Northeast Region Environmental Management, Research, and Education Centre (NEMREC), once it has been created and operationalized.

4.1.1 Ministry of Environment and Forests

An MOEF official with proper authority should be selected to oversee project implementation, delegate technical responsibilities to Forest Department staff, and to Environment Department staff, particularly in the Directorate of Environment Pollution Control.

4.1.2 Executing Agency

The Executing Agency would be contracted by the donor agency. The Executing Agency would consist of foreign and Bangladeshi consultants, including individuals contracted through NGOs such as NACOM and IDEA.

4.1.3 Local groups

Project activities would be undertaken in partnership with local groups. In general, these would be organized by NGO-source staff, based on existing local organizations. An early task of the project would be to complete a project participation plan, itself based on some initial consultations.

The biodiversity activities would work primarily through locally-managed Conservation Centres set up at each key wetland site which would serve as the focus for networks of local people in selected villages. Types of resources management stakeholders involved would include families dependent upon the open water fishery; owners and caretakers of grazing stock; wetland product gatherers; hunters and trappers; fisheries lessees; Government and NGO representatives; students and youth; and so on.

The surface water quality activities would involve local groups from the SPPM locality, and representative urban and rural groups with covering the range of interests in water quality. Stakeholders would include persons with interests in fisheries, industry, public health, local communities, and so on.

4.1.4 Northeast Region Environment Education, Management, and Research Centre

NEMREP will develop plans for the organization, setting up, and staffing and staff training of a private non-profit regional environment centre, reflecting among other things input from the range of interested parties — local groups, existing national NGOs with an interest in environment, existing regional NGOs, academics, and so on. NEMREP would then assist a charter committee to create and set up the Centre. Once the Centre has been created and operationalized, its role in the project will be formalized by appropriate means agreed to among MOEF, EA, and Centre directors.

The overall goal of the Centre would be to provide sustainable regional leadership in environmental management. One specific objective would be to take over all ongoing (recurrent) NEMREP activities. The ongoing funding stream would likely be similar to that of existing successful Bangladesh NGOs, that is, consist of a mix of donor, international NGO, private donation, and self-generated funds; part of the operational plans would deal with developing an adequate, stable funding base. The NEMREC should be given an initial endowment, the interest from which would be enough to cover at least operating expenses.

4.2 PUBLIC PARTICIPATION

Public participation in the project would be through the local groups mentioned above which would work in partnership with the EA (mentioned above), and, after NEMREC is operationalized, with NEMREC. In additional, specific project activities would include public participation in workshops, seminars, and so on, as needed.

4.3 INSTITUTIONAL DEVELOPMENT PARTICIPANTS

Institutional participation in the Institutional Development Component will be much broader than the institutions listed above. An institutional participation plan for each of the elements of this component would be developed such that all relevant bureaucratic, technical, and public interests would be adequately represented.

5. IMPACTS AND MULTI-CRITERIA ANALYSIS

5.1 INTRODUCTION

The material presented in this chapter is required for all project studies prepared under the Flood Action Plan. Additional documentation on the Initial Environmental Evaluations is included in Annex D.

5.2 BIOPHYSICAL IMPACTS

The intent of project is to mitigate the adverse biodiversity and surface water quality impacts of continuing human utilization of wetland and upland landscapes. Thus, the large-scale biophysical impacts of the project are expected to be highly beneficial.

Localized adverse impacts are possible, however, as part of specific biodiversity and surface water quality management interventions, but these cannot be characterized until more detailed plans are developed. For example, species or community recovery actions developed by local groups may be accompanied by adverse impacts in terms of changing land use or livestock management; as part of the local planning process, these impacts should be identified and managed acceptably (mitigation, compensation, monitoring, and so on). Pollution abatement schemes will involve modification/construction of wetlands, and as such displace existing land use; this, and any other potential adverse impacts, should be recognized and managed.

5.3 SOCIAL IMPACTS

Again, the intent of this project is to improve the environment for the benefit and largely through the agency of local people.

The socioeconomic and gender equity of impacts will be an important issue which should be carefully examined as interventions are planned and implemented.

- Biodiversity: On the one hand, the poorest men and women tend to be most dependent, certainly in relative and perhaps sometimes in absolute terms, on 'free' natural biological production. On the other hand, very rich influentials already control a great deal, perhaps most, of wetland production through the leasing system (which is applied not only to fish, but in some cases also to swamp forest trees, reeds, and grasses), and the benefits of improved productivity would in all likelihood flow disproportionately to them. In addition, improving the condition of degraded systems could increase the interest and motivation of the powerful to restrict local people's access even further.

- Surface water quality management: Socioeconomic and gender equity of impacts should be highly favourable. While the rich can afford to pay to shield themselves from pollution to some extent (through tube wells, good quality housing, uncontaminated food, medical care, and so on), the poor cannot. Women will benefit as much or more

than men. Among other things, clean water improves health, which will lighten women's burden of caring for sick children and other family members.

5.4 COST/BENEFIT CONSIDERATIONS

It has been argued (mainly in Section 2.4, Rationale) that the objectives to be achieved by this project are necessary, desirable, and of high priority. To achieve these objectives, technical options were evaluated and chosen based, in part, on cost-effectiveness. Thus, the project is intended to achieve certain tangible and intangible benefits of importance to the region at the lowest cost, given the biophysical, social, and technical constraints.

The tangible benefits would include increased sustainable open water fish production as a result of improved habitat, including reduced pollution; increased sustainable production of valuable biomass products for fuel, building materials, industrial and cottage industry input; increased sustainable production of tradeable animal products such as skins, oils, meat, bone, shell, and so on; increased sustainable output from grazed lands; production of duckweed aquaculture fish food; and so on. Given the innovative nature of the interventions proposed, quantification of these benefits would be difficult and is not attempted here.

Intangible benefits would include cleaner water for human consumption and other uses; erosion protection for haor villages; enhancement of landscape elements valued for aesthetic, cultural, religious, and recreational reasons; preservation of the national heritage of natural biological systems, communities, and species; and so on.

5.5 SUSTAINABILITY CONSIDERATIONS

Again, the intent of the project is to impart sustainability to the management of biodiversity assets, and to reduce surface water pollution which threatens various human and natural systems.

Social sustainability: The planning and implementation of interventions by the Executing Agency and local people in partnership is intended to improve the likelihood of social sustainability. This is not, of course, the whole story. Conflicts within local communities; conflicts between local objectives and abstract criteria relating to biodiversity conservation and sustainability; the actions of outsiders; the weakness of institutional arrangements (e.g. land registration) and of institutional technical competence; and simple fatigue, are among the many risks to social sustainability.

Biophysical sustainability: The project intends to improve various aspects of biophysical sustainability, but admittedly will be trying to do so in an environment which poses some monumental challenges: high incidence of poverty and pauperization; high population density coupled with high dependence on natural systems; rapid development, social change, and urbanization; and so on. Our belief is that to move toward biophysical sustainability, this interventions included in this project are necessary but not sufficient; for success, they must act syncretically with actions taken to address these other challenges.

Population and Poverty: The current rate of population growth and the accompanying increase in poverty must be recognized as major obstacles to sustainable development. The project

Table 5.1 Multi-Criteria Analysis

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	**Rank**
Improved condition and management nine internationally significant wetland sites	5
Improved condition, management, & extent, three threatened communities	5
Recovery of numerous globally threatened animal and plant species	5
Reduced industrial pollution from Sylhet Pulp and Paper Mill	5
Reduced industrial pollution from existing & new smaller industrial facilities	5
Reduced domestic waste pollution from major urban centres and selected smaller towns	5
Improved institutional capability for biodiversity and surface water quality management	5
Potential negative localized impacts associated with management plans, pollution abatement facilities	-1
See also discussion in text	

assumed that population control and poverty alleviation, two priority activities of the Government of Bangladesh, would proceed simultaneously. Success of the proposed initiatives are contingent upon achievements of these programmes.

5.6 MULTI-CRITERIA ANALYSIS

The multi-criteria analysis of the Project is shown in Table 5.1.

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6. DETAILED DESCRIPTION OF WORK PACKAGES

6.1 INTRODUCTION

A detailed description of each project work package (component, element, and activity) is provided below. The order follows that shown in the work breakdown structure (Figures 3 and 4).

The level of detail varies among the packages, reflecting the information available to the study team in each area.

The Biodiversity component is composed of four elements:

- Locally-based management of key wetland sites
- Threatened ecological community recovery
- Threatened and commercially threatened species recovery
- Upland biodiversity conservation studies and implementation

COMPONENT: **BIODIVERSITY**

ELEMENT: **Locally Based Management of Internationally Significant Wetland Sites**

Location Nine key wetland sites (Hail Haor, Hakaluki Haor, Tangua Haor, Pasua Beel, Baulai Haor, Kawadighi Haor, Bara Haor, Companiganj Area, Khaliajuri Area)

Area 83,800 ha

Population Impacted Direct: inhabitants of wetland sites — 29,000 (1991); 36,000 (2015). Indirect: national/international.

Objectives General — Conserve biodiversity at the ecosystem level and wetlands of international significance, by stabilizing the ecological character of the nine most important remaining semi-natural wetland sites.

Site specific — Objectives for each site will need to be formulated based on consultations with stakeholders (local residents and other interested parties) with regards to (for example):

- Slow, stop, or reverse habitat loss, focusing on key elements such as mature trees
- Slow, stop, or reverse rates of species population decline, focusing on threatened species
- Stabilize or increase long-run economic returns to wetland users of valued wetland products, through biological management to achieve high sustainable yields; improved access to e.g. markets, technology, credit; and other improvements
- Create economic returns to local communities through ecotourism
- Manage conflict between different users and user groups
- Enhance socioeconomic and gender equity

Background Improved management of wetland resources in the region should focus on the nine wetland sites which have been identified as meeting one or more Ramsar Convention criteria for international significance.

The emphasis should be on assisting stakeholders to design and implement management plans that enhance both biodiversity values and sustainable benefits flowing to local communities. This approach mobilizes local resources, minimizes central government dependency, and reduces conflicts between conservation and utilization objectives.

A methodology to create locally-based natural resource management systems has been developed by the NGO NACOM through its work at several sites (Kapasia, Munshiganj, and Teknaf). The approach is built around a network of volunteers who are identified based on direct involvement with and dependence on resource utilization, residence near the resource, with an expressed interest in protecting their natural and cultural heritage, and other criteria. Activities of the volunteer

network are coordinated through a Conservation Centre established in each area and staffed by a core group of local people who are given necessary training and technical support. Activities for men, women, young people, and children are used to create community awareness, exchange information, and address community concerns such as resource management, income generation from natural resources, and so on.

In addition, two opportunities to enhance this methodology exist. Under NERP, the NGO IDEA carried out extensive social anthropology studies at a number of sites in the Northeast Region. The methodologies used, the information generated and the experienced personnel from these studies all represent resources that could be tapped by NEMREP. Also, the ZOP (goal-oriented programming methodology) is being actively supported by German Technical Assistance (GTZ) in Bangladesh. Courses are offered on an ongoing basis, targeted to NGO personnel but open to all, at the GTZ office in Dhaka; plus, existing trained and experienced ZOP facilitators can be hired through them.

Content

At each key site,

- Baseline studies: ecological and resource use studies; identification of wetland resource users and other interested parties; participatory analysis of concerns, driving forces, strengths, weaknesses, opportunities, and threats, and setting of wetland resource management objectives. These studies parallel the NERP *Wetland Resource Specialist Study* on a site-specific basis and lay the foundation for the next two steps
- Build up network of volunteers and establish a Local Conservation Centre.
- Using a participatory planning methodology (e.g. ZOP), develop a site management plan based on input from local and other resource users, supported by needed technical and policy/regulatory inputs from technical experts, government representatives, etc. Management plans could include provision for local organization, training, technology transfer, credit, agreements between local organizations and government agencies, government action, identification of possible structural measures, and so on. The role of NEMREC in providing ongoing inputs from outside the local system would be explicitly specified
- Implementation of management plan on a trial basis
- Participatory monitoring and evaluation

Management plans might identify structural measures as possible contributors to reduce threats from sedimentation, conflicts between agriculture and fisheries, or other processes. In such cases, pre-feasibility and/or feasibility study(ies) would be undertaken by an interdisciplinary technical study team in partnership with local resource managers; and, funds permitting, feasible small-scale structural components implemented. Larger, more expensive initiatives would have to be implemented with other financing, perhaps after incorporation into an FCDI or other infrastructure project. Participatory operation and maintenance of these structural components would be key.

Once the objectives and process described above were completed, NEMREC would take over provision of needed ongoing inputs to ensure that gains achieved can be sustained and progress continued. The types of ongoing inputs that might be required of NEMREC are described on the NEMREC element sheet.

Outputs

For each site, Baseline Study Report; Management Plan; Monitoring and Evaluation Reports. For each of these, reporting media (pictorial, photographic, audio-video) and formats oriented to participatory methodologies would be used as appropriate. For sites where structural measures are proposed, as appropriate, Pre-feasibility Study, Feasibility Study, detailed designs, and construction.

Inputs

For baseline studies and management plans, local staff would be organized into three supervisory teams of three senior local professionals each (wildlife biologist/ornithologist, botanist, and participatory planning/institutional specialist) and nine field teams (one at each key site) of four local staff each. Training of these teams in project management, participatory methodologies, and biological field skills would be required before and during field mobilization.

For any structural measures, feasibility study teams. For small-scale structural measures, design teams and construction monitors, and construction funds.

Supporting inputs in all areas would be supplied by the expatriate Team Leader and technical specialists.

Linkages

Within NEMREP: to Threatened Community Recovery; Threatened Species Recovery; and NEMREC. To other NERP proposed initiatives: Fisheries Management.

Assumptions

Ongoing support of objectives by local and central government agencies. No intractable constraints or conflicts to improved wetland resource management at the sites. Perceived benefits of improved management are significant enough to motivate resource user participation. Adequately trained and highly committed local staff. Project staff and government participants respectful of local resource users, and show flexibility and creativity in integrating local perspectives with biological, technological, and institutional considerations.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened Ecological Communities**

Location Swamp forest, floodplain grassland, and Forest Department reed swamp areas plus suitable other areas

Area Existing communities: about 2300 ha known. Areas suitable for habitat restoration: not known; an additional 18,000 ha of Forest Department reed land is thought to be unencroached.

Population Impacted Direct: Local. Indirect: Regional/National/International.

Objectives General: rehabilitate, extend, and sustainably manage lowland ecological communities once characteristic of the region that have all but disappeared.

Description Lowland forest, reed lands, and floodplain grassland are key elements of lowland biodiversity. All three are threatened as ecological communities. In addition, these resource systems provide direct economic and other benefits to local people; enhance openwater fishery and wildlife habitat and fishery productivity; protect homesteads from wave erosion; improve water quality; and stabilize land use.

The proposed intervention is to use appropriate locally-based methodologies to re-establish these communities over suitable areas. The techniques used for each community will differ, reflecting the different strengths, weaknesses, opportunities and threats applicable to each.

Content This Element consists of three Activities:

- Swamp forest studies, habitat restoration, and management
- Floodplain grassland studies, habitat restoration, and management
- Reed swamp studies, habitat restoration, and management

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COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened Ecological Communities**
ACTIVITY: ***Swamp forest***

Location Existing swamp forest areas plus other swamp-forest suitable areas

Area Existing area 1000 ha. Potential additional area not known.

Objectives General —

- Document existing swamp forest conditions and current plantation efforts
- Conserve existing swamp forest habitat
- Complete needed preparatory work that is prerequisite to swamp forest habitat restoration on a large scale

Specific —

- Document biophysical conditions and management systems in selected existing swamp forest patches; and ongoing private afforestation practices
- Conserve existing swamp forest by working with users and managers at selected sites to make management/use practices more sustainable
- Develop effective, field-tested biological/social model(s) for swamp forest community habitat restoration (afforestation) and sustainable management
- Develop effective, field-tested methodologies to encourage private sector and community afforestation and improved management
- Establish necessary biophysical, social, tenure, and other criteria for identifying sites whose best use is swamp forest
- Generate an inventory of candidate sites for swamp forest habitat restoration throughout the region

Background Much of the area of the Northeast Region now under rice would once have been occupied by lowland forest. Remnant patches are now located on areas sloping way from village highland down towards the haor, on elevated ridges between beels, and on stream levees.

In addition to its importance as an element in regional biodiversity, swamp forest provides numerous important products and services, to the wetland ecosystem and to society:

- Protects homesteads on the haor margins from wave erosion
- Enhances openwater fishery habitat
- Increases openwater fish production
- Generates biomass products (branches for katha, fuel wood)
- Generates income for local people

These roles of swamp forest in the region were recognized in the NERP planning process, and swamp forest habitat restoration was included in several proposed initiatives: Fisheries Management (fisheries habitat); Village Afforestation (homestead erosion protection); and Applied Research for Improved Farming

Swamp forest *continued*

Systems in the Deeply Flooded Area (income generation in the deeply flooded area farming systems). Some private swamp afforestation is already occurring, which suggests that, in suitable settings, economic returns to land owners and fisheries lessees are competitive with other rural investment opportunities.

The thrust of NEMREP's work with swamp forest is (1) to conserve existing swamp forest habitat, and, (2) in preparation for large-scale swamp forest habitat restoration under the initiatives mentioned above, to develop an understanding of swamp forest biology and management and to field-test models and methods for swamp forest habitat restoration and for enhancing and supporting private plantation efforts.

Content

The first step would be to understand biophysical conditions (especially as regards natural and induced regeneration) and management systems at existing swamp forest patches, with particular attention to trends.

To address the need to conserve existing swamp forest, current management practices at selected sites would be subjected to a participatory analysis to identify constraints and problems (e.g. conflicts, insecure tenure, inappropriate monetization, income pressures, fuel shortages, theft) and opportunities (e.g. feasible measures to enhance natural regeneration). Implementation of promising management improvements by users and managers would be supported (e.g. through education, brokering agreements between user groups) and monitored by the project.

The private afforestation efforts already in evidence in the region are also of great interest. Locations, methods, rates, economics, etc., would be documented.

Based on this information, pilot afforestation projects would be undertaken at selected sites to test models for afforestation. These models would have to deal with both biological and social aspects of habitat restoration, seedling protection, coppicing, etc. These models would then be usable by both public social-forestry programs and by private parties (NGO, community, entrepreneurial) engaged in afforestation.

In addition, possible methods to encourage private afforestation need to be identified and field tested. These could include public meetings, radio and TV messages, school activities, etc. In some settings, there will also be a need for tenure/management arrangements between landowners or leaseholders and tree planters/managers; credit; seedlings; etc.

As an adjunct to these efforts, a set of necessary (but not sufficient) biophysical, social, tenure and other criteria need to be developed which are descriptive of sites whose best use is swamp forest. These would then be used in generating an inventory of candidate swamp forest sites throughout the region.

Swamp forest *continued*

Once the objectives and process described above were completed, NEMREC would take over provision of needed ongoing inputs to ensure that gains achieved can be sustained and progress continued. The types of ongoing inputs that might be required of NEMREC are described on the NEMREC element sheet.

Outputs

Reports/memoranda:

- Interpretive description of existing swamp forest and swamp forest plantation
- Data and analysis from monitoring of management improvement experiments
- (A) Field-tested biological and social model(s) for swamp forest habitat restoration
- Field-tested methods to encourage and support private swamp forest habitat restoration
- Criteria (biophysical, social, tenure, and other) for identifying sites suitable for swamp forest habitat restoration
- Partial regional inventory/map of sites suitable for swamp forest habitat restoration

Biophysical/social outputs:

- Improved management at selected existing swamp forest sites
- Improved awareness of swamp forest values and management at selected sites
- Swamp forest habitat restoration at pilot model test sites

Inputs

Local and expatriate project staff. Field research and pilot restoration facilities.

Linkages

Within NEMREP: to Key Wetland Sites and NEMREC. With other NERP proposed initiatives: to Fisheries Management, to Village Afforestation (documented in the pre-feasibility study *Development of Rural Settlements*).

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened Ecological Communities**
ACTIVITY: ***Floodplain grassland***

Location	Existing floodplain grass land areas plus other grassland-suitable areas
Area	Existing area about 500 ha. Potential additional area not known.
Objectives	Sustainable social management of the remaining 500 ha of grassland, plus habitat restoration in any areas for which this is found to be the best use.
Background	Floodplain grass land area is extremely limited and little studied, but of importance as habitat for a number of bird and other species some of which may have already disappeared from the region but could perhaps be reintroduced. More study of this community is needed, along with preservation of the small fragments that remain.
Content	• Baseline studies — literature review, mapping and characterization of existing grass lands, study of current management, exploitation, etc. • Preparation of habitat restoration and sustainable management methodologies • Implementation of pilot/demonstration restoration/management schemes
Outputs	Reports/memoranda and biophysical social outputs.
Inputs	Local and expatriate project staff.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened Ecological Communities**
ACTIVITY: ***Reed swamp***

Location Existing reed swamp areas plus other reed-suitable areas

Area Existing area in good condition 800 ha. Potential additional area not known, but an additional 18,000 ha of Forest Department-owned reed land is thought to be unencroached

Objectives General — Social afforestation and sustainable social management of 19,000 ha of unencroached Forest Department reed land, plus suitable areas (yet to be identified) under other ownership.

Specific —

- To conserve and enhance the currently threatened reed community (dominant species *Phragmites karka* 80% and *Saccharum spontaneum* 20%)
- To benefit openwater fishery production
- To create employment and income for local people
- To achieve attractive rates of economic return in the sustainable production of industrial input material for regional pulp and paper manufacture at the Sylhet Pulp and Paper Mill (SPPM, Chhatak)
- To mitigate biomass and pulp shortages expected to start in 2000 due to gregarious flowering and large-scale natural death of the main forest bamboo species, muli (*Melocanna baccifera*)
- To substitute for pulp imports

Background The reed swamp ecosystem of the Northeast Region has all but disappeared. Of the 36,000 ha of reed area found in surveys in the 1960s, only about 8000 ha is estimated still to be under reeds, of which only about 800 ha (3%) is though to be in good condition (none is in excellent condition); most is highly degraded.

Reed swamp provides a variety ecosystem services and products. It supports the productivity of the openwater fishery through a variety of means (water purification, habitat, substrate for food species), so much so that fishery leaseholders in some areas are guarding natural regeneration of reeds to increase production within their fisheries. Reeds have been harvested for building material, input to the pulp industry, and for fuel, principally for lime-burning.

Most (27,562 ha) of the historic reed land, and virtually all of the remaining reed area, is owned by the Forest Department as nominal reed land in Acquired Forests in the North Sylhet and Sunamganj Ranges (Table 6.1). Figure 6.1 illustrates the current status of FD reed land; Table 6.2 gives a more detailed breakdown.

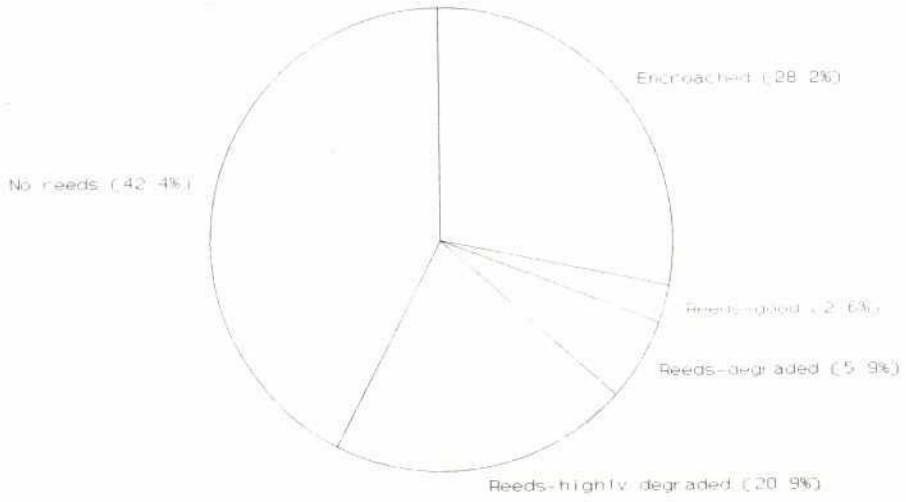
Responsibility for most (22,267 ha) of the Forest Department reed land was given to SPPM upon beginning operation in 1976. In 1993, SPPM proposed to

return the areas to the Forest Department; at this writing, this transfer had not yet taken place, however, and the reed lands remained under SPPM tenure. The Forest Department has already prepared a proposal for plantations of *Cyperus rotundus* murta and *Calamus tenuis* jalibet, a type of cane, both of which are in good demand as raw materials, to make mats and furniture respectively. These plants are more typical of somewhat higher vegetation communities, however, and the technical feasibility of plantations in reed swamp-suitable areas should be carefully checked.

Three main historic processes, all in decline or no longer operating, were the driving forces behind the gradual degradation and destruction of the reed community:

1. *Overcutting for fuel for lime-burning*. Until the mid-1980s, demand for fuel by hundreds of very small village-based lime-burning units and one medium-sized unit in Sylhet. All units switched to natural gas in the 1980s.
2. *Weak SPPM biological management*. Initially, SPPM had no biological management capability and engaged only in harvesting. It is thought that Initial reed-cutting was too aggressive, leading to poor regrowth, mill input

Figure 6.1: Current status, Forest Department reed land



shortages, and, eventually, shifts to other sources. SPPM apparently replanted 2000 ha at one point; NERP has not been able to determine the outcome of this effort.

3. *Encroachment by agriculture*. Rates of encroachment are likely decreasing, as the more cultivable areas have already been converted to agriculture and severe flooding in recent years may be discouraging farmers already in marginal areas.

Other threats, of more localized significance, are continuing:

- Overcutting for local uses such as building material
- Siltation
- Destruction of rhizomes due to trampling by buffaloes (heavier than cows)

Table 6.1: Current status, Forest Department reed lands

Category	North Sylhet Range		Sunamganj Range	
	ha	%	ha	%
Total area[1]	17256	63	10306	37
Existing reeds	7287	42	810	8
Excellent condition	0	0	0	0
Good condition	729	4	0	0
Degraded	1457	8	162	2
Highly degraded	5101	30	648	6
Without reeds	9969	58	9,496	92
Converted to other land uses	3987	23	3798	37
Unencroached	5981	35	5698	55
Total potential plantation area[2]	12,539	73	6,508	63
Total potential reed area[3]	13,269	77	6,508	63

Source: NERP estimates; nominal accuracy $\pm 10\%$.
[1]These percentages relative to total area (both Ranges). All other percentages relative to Range area.
[2]Total of degraded, highly degraded, and unencroached areas.
[3]Total Forest Department area less encroached area; equivalently, current excellent and good areas plus potential plantation area.

The original concept for SPPM, in a feasibility study prepared by Sandwell in the 1960s, was to use reeds as the main or only input material, but the mill was eventually constructed to use a combination of bamboo, reeds, and jute cuttings. Despite the name, the mill produces pulp only, having a design capacity of 30,000 air-dry tonnes/year, about 25% of the 126,000 ADT/yr national pulp capacity. Since 1988, production has been about 18,000 air-dry tonnes (only 60-65% of design capacity and only 6% of national production), due to serious shortages of raw materials. Since 1989, 70% of SPPM input is from the private sector, composed of about 63% bamboo, 32% pulpwood, 4% jute cuttings, and 1% reeds (Draft Forestry Master Plan, 1993, p. 96).

Table 6.2: Reed areas of the Sylhet forest division

Range	Name	Reed area (ha)
Sunamganj		
Reserved Forest[1]	Laurgarh	497
Acquired Forest[2]	Dipchar	355
	Karaigara Ban San Mahal	607
	Puran Bashtala Ban Mahal	202
	Karchar Haor Ban Mahal	648
	Das-sena Ban Mahal	405
	Eratia Purangoan Ban Mahal[3]	810
	Tangua Haor	1012
	Barakhia Parua; Chatiba Paligaon	4209
	Khadanchibari Ban San Mahal; Ray and Chera Estate Ban San Mahal	1562
Range total		10,307
North Sylhet		
Acquired Forest	Gouripur Nizgaon Ban Mahal	1012
	Dhargram Banker Mahal (includes Ranikhai Reserve Forest)	2591
	Copaniganj Dastidar Estate	2508
	Pyangul Banker Mahal	3468
	Chailtabari Lengura Ban San Mahal	4163
	Chailakhal Baun Haor Ban San Mahal	3514
Range total		17,256
TOTAL		**27,563**

[1]Reserve Forests are regulated by the provisions of the Forest Act, 1927.
[2]Acquired Forests are forest areas taken over from *zamindars* by the Government under the State Acquisition and Tenancy Act, 1950. These were to be declared and managed as Reserve Forests following due legal process to be undertaken by the District Commissioners as Forest Settlement Officers. The inquiries in most cases have yet to be completed, reflecting the confused state of land claim records. Current thinking is that title over occupied land, or agreements as to continuous use, should be given to the individuals involved (Forest institutions, App. 6, p. 7; Forestry Master Plan, 1993).
[3]Proposed Reserve Forest.

Recent information provided to NERP, as yet unconfirmed, indicates that SPPM is being altered to accept jute as its main input.[4] Questions which should be investigated include whether reeds would still be acceptable, accepted, and economically competitive as input to SPPM. If so, reed production for industrial input would still be a viable option, if the biological and social problems can be managed (overcutting, encroachment, illegal cutting, etc).

Future demand for pulp and paper is expected to increase rapidly, in keeping with increasing population, increasing literacy, and increasing wealth per capita, from an estimated 140,000 ADT in 1993 to between 194,000 and 284,000 ADT in 2003; and 245,000 and 462,000 ADT in 2013 (the low estimates uses historical population growth and literacy increase rates; the high estimate corresponds to a "US$400 per capita GDP economy.") Forest product and biomass supplies are not expected to grow anywhere near this quickly, especially as the main forest bamboo species has begun gregarious flowering and will have died back by 2003. This suggests that biomass and forest product price trends will favour producers, absent distorting interventions.

With reasonable management, sustainable reed yields are believed to be 4.5 T/ha-yr raw weight or 0.67 tonne/ha-yr dry weight. The total potential Forest Department reed area is about 19,000 ha (Table 6.2). Assuming this yield and area, reed production would be at most 7800 ADT/yr. Incremental production attributable to plantation would be 7600 ADT/yr, if current reed input to SPPM is 180 ADT/yr (assuming that FMP figures of 18,000 ADT/yr for SPPM pulp production and 1% reed input are representative). The scope for reed habitat restoration in areas owned by entities other than the Forest Department (such as Ministry of Land or private landowners) should also be assessed.

Natural regeneration of reeds is rapid under suitable conditions (physical plus adequate availability of parent stock). Where parent stock is insufficient, an initial plantation would be required. Plantation is straightforward technically. At the time of flood recession, rhizomes are collected from plants in source areas of 'degraded' or better condition. Rhizomes are planted in suitable target areas by inserting the rhizomes directly into wet earth at a density of about four per square meter. The first harvest is in the fifth year or so, when plants reach a height of about two meters. Mowing is by hand, taking care not to cut too close to the root systems, which seems be the reason for poor regrowth and gradual degradation in many cases where harvesting is attempted. Subsequent harvests should be every other year or less in frequency. Plants self-propagate by creating new rhizomes, and properly managed stands should increase in productivity for a number of harvest cycles, eventually levelling off.

[4]As this was written, however, articles appeared in which increased use of jute for paper pulp was characterized as experimental or in the early stages of practical implementation (*Daily Star*, 1993; *Down to Earth*, 1993).

Table 6.3 shows a trial economic analysis of reed plantation. Estimated input costs are 100% local labour. Costs were not estimated (assumed zero) for rhizomes, which would be taken from FD standing stock; transportation of rhizomes; and basic transplantation equipment (baskets, hand tools).

Swamp forest habitat restoration may be an better option on some or all of the Forest Department nominal reed land. Ecologically, the North Sylhet Range area is all highly suitable for reed habitat restoration, whereas the Sunamganj range is a bit drier and thus somewhat less suitable for reeds and somewhat more suitable for swamp forest. Social, economic, organizational, and other factors would also need to be examined.

Table 6.3: Economic analysis, reed plantation

Net present value at 12%, Tk/ha	174
Rate of return, % per year	14.0
Input parameters:	
Labour wage rate, Tk/p-day	33
Sq meters per plant	0.25
Plants per ha	40000
Transplant rate, p-hr/ha	200
Transplant cost, Tk/ha	813
Patrol cost, Tk/ha-mo	4
Harvesting cost, Tk/ha	163
Ratio, target area/degraded source area	10
Harvest yield, wet tonnes/ha-yr	4.5
Ratio, wet T/ADT	11
Harvest cycle, years	2
Proportion used locally	0.2
Farmgate price, Tk/wet tonne	139

Content

- Background studies: literature review; baseline studies of reed lands — current land use, *de facto* tenure, current biological status and management, recommended best future use (current use, reed, swamp forest, other); institutional review in the area of social forestry; review of SPPM reed land management experiences; assessment of SPPM attitude towards future reed purchases; economic analysis of reed plantation; assessment of scope for reed plantation on non-Forest Department-owned areas
- Development of pilot/demonstration social forestry schemes for reed plantation, involving the Social Forestry Division of the Forestry Department, local residents, and an NGO. This will need to deal with land tenure, source of inputs, distribution of benefits, policing, reed management education for local groups. Plantation could be undertaken as a Food-for-Work activity.
- Evaluation of pilot schemes, revision
- Replication facilitated by demonstration, training, input assistance, and other means

Outputs

Background Study Report; Pilot Scheme Design(s); implemented Pilot Schemes; Evaluation and Revision Report; Replication Plan and implementation

Reed swamp *continued*

Inputs Local and expatriate project staff.

If plantation is undertaken:

- NGO(s) as part(ies) to social forestry agreement(s), and staff provided by them.
- Financial investment (costs in years 1 through 4 until first harvest): US$680,000, assuming 19,000 ha planted at a cost of Tk 1442 (US$36) per hectare.

Linkages Within NEMREP: to Key Wetland Sites; Swamp Forest Habitat restoration; Pulp and Paper Mill Effluent Abatement; Threatened Species Conservation; NEMREC. With other NERP proposed initiatives: to Fisheries Management.

Assumptions Land owner (Forest Department, Ministry of Land, private) interest and involvement. For reed plantation: economic feasibility based on SPPM demand for reeds.

COMPONENT: **BIODIVERSITY**
ELEMENT: *Threatened and Commercially Threatened Species*

Scope Regional

Population Impacted Direct: Local. Indirect: National/International.

Objectives Ensure the survival of viable populations of extant animal and plant species. Determine feasibility considerations of re-establishing populations of species now extinct from the region. Specific objectives must be formulated for each threatened or commercially threatened species, based on consultations among local people, technical experts, landowners (principally GOB), and government; and taking into current strengths and weaknesses and future opportunities and threats in the areas of technical means, ecological and social considerations, and so on.

Content This element consists of nine activities:

- Raptor recovery — Pallas's Fish Eagle
- Waterfowl populations and threatened lowland bird species
- Aquatic mammals
- Small terrestrial mammals
- Large mammal and reptile species
- Freshwater turtles
- Reptile/amphibian farming
- Bengal rose
- *Eurayle ferox*

In addition, recovery of threatened/commercially threatened upland species (see the initiative *Upland Biodiversity Conservation*) and any other lowland taxa subsequently identified should also be undertaken.

Objectives

To support a 10% annual increase in the number of known nesting pairs of Pallas's Fish Eagle *Haliaetus leucorhyphus* in the Northeast Region (from the current level of 36 pairs to 100 pairs by 2005 and 430 pairs by 2020). The rate is a guess and should be reviewed against previous experience in raptor recovery programs and on additional field research.

Background

Pallas's Fish Eagle is listed in the Red Data Book (IUCN, 1990a) in the category Rare. The 36 nesting pairs observed in the Northeast Region during NERP are of international significance as the largest actively breeding population seen in recent years throughout the range (D. Scott, pers. comm.).

This species is a raptor (diurnal bird of prey), a group which is a major component of Order Falconiformes. It is a large dark brown eagle with pale golden brown head and neck, and a broad white subterminal band across a rounded (not wedged) tail. Sexes are alike and the female is slightly larger. Ear covers are dark, and underparts are paler and greyer. Immature birds are dark brown, with very dark wing quills and unbanded tail (Ali and Ripley, 1983).

The total range of this species extends from south Russia through Central Asia to Transbaikalia and south to the Persian Gulf, north India, and north Burma (Myanmar). In South Asia, this species is resident and partly migratory in Pakistan and Northern India up to about 1800 m altitude in the Himalayas, from Kashmir, Himachal Pradesh, Punjab, Nepal (valley and lowlands) through the Gangetic Plains east to Assam and Bangladesh, south to a line roughly from Surat (21°10'N) to Gopalpur (19°20'N) south of Chilka Lake in Orissa. It breeds in areas up to about 1800 m altitude in the Himalayas and more or less wherever found in the plains. The lowlands of the Northeast Region of Bangladesh (i.e. the entire region except for the hilly areas) currently provides suitable breeding habitat for this species.

The species is territorial, and even under optimal conditions low population densities reflect a preference for large territories (up to 10,000 ha per pair). Populations appear to be declining at an alarming rate almost everywhere. In the mid-1980s, it was feared that the species had become endangered in Bangladesh, with perhaps only a few breeding pairs remaining (Husain and Sarker, 1984). During recent years, habitats in Bangladesh have been progressively degraded; now most of the large trees are gone, overfishing and lack of biological management have reduced fish stocks, and wetland ecosystems have been reduced in quality and size due to expansion of agriculture and flood control schemes.

The species frequents the neighbourhood of large rivers, tidal creeks, inland lakes, and jheels. It is normally seen perched on a mound, fishing stake, or tree top by a jheel, on a sand bank in a river, or sailing aloft in wide circles calling periodically. Its food is chiefly fish, but also water birds, like coots, purple

moorhens, and sometimes even larger birds. Snakes, frogs, mud turtles and carrion have also been recorded. The nest is a huge stick platform, usually lined with green leaves, which is built 15 to 35 m up in a large tree, standing near or in a swamp, river, or lake, often on village outskirts. Usually three, sometimes two or four, eggs are laid; these are white and unmarked, about 7 cm by 6 cm in size. The breeding calendar as deduced from NERP observations is shown in Table 6.4.

During September 1992 to May 1993, individuals were observed in the region; during June, July, and August 1992 none were observed. It is reasonable to assume that during the summer the birds migrated out of the region to upland areas — possibly to the treeless Kailas-Manasarovar region of West Tibet where in summer it has been observed in large numbers (Ali, 1965). In winter, the Northeast Region provides tree sites for nesting and a plentiful fish supply at a time when upland streams are frozen. In summer, the Northeast Region is flooded and fish populations are dispersed and thus difficult to catch, at a time when fish are abundant in the meandering streams and bogs dotting the uplands. Similar observations of seasonal presence in the lowlands are reported from the Salt Lakes near Calcutta where the species was found to be very common and breeding conspicuously about between October and April but absent between May and September.

Though these birds prefer high (15 m and more) nest sites, nests were observed at elevations as low as 5 m, presumably due to a shortage of tall trees. Reproductive success is probably much less at such heights, due to greater vulnerability to predation and other threats.

A shortage of prime nesting sites appears from the NERP observations to be an important constraint to this population of this species. Additional field research

Table 6.4: Breeding calendar, Pallas's Fish Eagle

Activities	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Call	*	*	*	?			*	*	*					
Display			*	?										
Mating						?	?	?						
Nest making							*	*	*					
Incubation								*	*	*	*			
Eggs hatched											*	*		
Fledglings												*	*	*

* observed by NERP ? presumed

would be required to assess if any other constraints within the region or on the species' summer range are operating.

Content Proper project design and implementation will require collaboration with one or more existing raptor recovery programs, of which there are a number in North America and Europe (there are at least two in Canada). The main elements of the project would probably be:

- Provision of nesting platforms. Designs would have to be developed and tested, then the best design would have to be replicated in sufficient numbers at suitable sites in the region. Costs will be sensitive to the height and engineering stability required. Platforms on electric pylons are an option (some existing nests are on pylons), but pylons are few in number and present only in a few areas.

- Further study. This will be necessary as part of the platform design evaluation, and to evaluate what other constraints are operating on the population.

Afforestation, local awareness-raising to reduce harassment and capture, and habitat preservation and enhancement, will also be necessary; these are being addressed under other NEMREP elements (see below under Linkages).

Outputs Nesting platforms. Field research reports, including recommendations for linked NEMREP elements.

Inputs Collaboration with one or more established raptor recovery centres, and technical assistance from a raptor recovery specialist. Local ornithologist. Platform construction materials and labour.

Linkages Within NEMREP: Swamp Forest Habitat Restoration, Reed Habitat Restoration, and Key Wetland Sites.

Assumptions Necessary links with raptor recovery centre(s) can be established. Nest sites are currently the main constraint, and technical feasibility of nesting platform approach for this species; or, correct constraint and approach can be identified and implemented.

Objectives

- Reduce hunting, disturbance, and other threats to the region's waterfowl population
- Monitor Baer's Pochard *Aythya baeri* in the region, in collaboration with international waterfowl monitoring and conservation efforts
- Reintroduce, assist the voluntary reappearance of, or enhance the currently very low populations of, nineteen lowland bird species which are either regionally extinct, present but no longer breeding, or of unknown status.

Background

The region's waterfowl population as a whole is of internationally significance and deserving of improved management. NERP's observations of the waterfowl of the Northeast Region are documented in the *Wetland Specialist Study*.

Eighteen of the bird species known or thought to have occurred in the lowlands of the Northeast Region are listed in the RDB (see Table 2.3). (In addition, there may be additional species listed which are known or thought to have occurred in the uplands of the region, but NERP has not systematically studied these.) Of these species, only two still occur in the region in internationally significant numbers: Pallas's Fish-Eagle (discussed in the previous work package) and Baer's Pochard.

Baer's Pochard is a diving duck recognized only in the 1950s or so as a species distinct from the more common Feruginous Duck *A. nyroca* which it closely resembles. It winters widely from south China through Vietnam, Thailand and Burma to northeastern India and occasionally even Nepal. It is everywhere rather scarce, however, and the concentration of 700 observed by NERP in the winter of 1992/3 is thus of considerable international significance. It is categorized as Vulnerable (IUCN, 1990a). NERP has as yet been unable to obtain any information on its detailed status or threats to it. As the Northeast Region of Bangladesh is on the southeastern limit of its winter range, recovery measures in the region may be of only marginal utility. In any case, monitoring would support global efforts to conserve the species.

The other sixteen listed species are either globally extinct (Pink-headed Duck *Rhodonessa caryophyllacea*), extinct from Bangladesh (six species), extinct from the region (two species), visit the region but no longer breed there (two species), are small birds dependent on reed and grass land habitat whose status could not be determined (four species); the remaining species, Blyth's Kingfisher, is more typical of forest streams, and was perhaps always only a rare visitor.

Content

Improved management of the waterfowl population would build on the characterization of current human/waterfowl interactions begun under NERP. These interactions are known to include disturbance, habitat degradation, hunting,

trapping, and poisoning of waterfowl by humans, and crop damage by waterfowl. The costs, benefits, and overall sustainability of the current pattern of interactions and exploitation would be analyzed, and local people consulted to devise ways in improve sustainability and benefits. A potential method already identified is establishment of locally-managed rotating waterfowl sanctuaries.

For Baer's Pochard, the appropriate action for NEMREP will be to monitor the species and establish contact and exchange information with researchers in other parts of its range.

The globally extant species which used to appear in the region's lowlands in significant numbers (fourteen species), would be candidates for voluntary or assisted reintroduction, and for special efforts to obtain observations of any individuals who are in fact present in the region. Efforts would focus particularly on those species which still visit and might reestablish breeding populations in response to habitat restoration and improved management. In support of this activity, NEMREP should develop and maintain an awareness of the progress in other countries of reintroduction programs and techniques for these and similar species. Successful models could be considered for replication in the Northeast Region.

Outputs Both reports/memoranda and biophysical/social outputs would be produced.

Inputs Local and expatriate project staff.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened and Commercially Threatened Species**
ACTIVITY: ***Aquatic Mammals***

Objectives

- Find any additional surviving populations
- Stabilize or increase numbers in existing populations
- Establish additional populations if possible
- Understand and reduce commercial and other threats

Background

All three aquatic mammal species currently found in the Northeast Region are listed as globally threatened or commercially threatened: Gangetic Dolphin *Platanista gangetica* shu shuk, the Eurasian Otter (also called Common Otter) *Lutra lutra* ud biral, and the Smooth Indian Otter (also called Asian Short-Clawed Otter) *Lutra perspicillata* shosh dharia or jaat dharia.

The Gangetic Dolphin is classified as Vulnerable (IUCN, 1990a) and is listed on CITES Appendix I (trade prohibited). The species is found in the Ganges-Brahmaputra-Meghna river system, and in the Karnaphuli River. Its distribution extends beyond Bangladesh to northern and eastern India, Nepal, and possibly into the Dihong and Sangpo Rivers in Tibet. It is one of a number of dolphin species that have become completely adapted to riverine life; the others are the Indus Susu *Platanista minor* found in the Indus River, the Beiji *Lipotes vexillifer* in the Yangtze River, and the Boutu *Inia geffrensis* and the Franciscana *Pontoporia blainvillei*, both found in the Amazon and Orinoco Rivers. All are blind but thought to be very intelligent.

Conservation of River Dolphins of the Indian Subcontinent was the title of an IUCN Species Survival Commission/Cetacean Specialist Group workshop held in New Delhi in August, 1992 (Reeves *et al.*, 1993). A number of threats to the species were identified, including man-made obstructions to migration routes (particularly dams), mortality in gill-nets (both incidental to fishing and deliberate capture), overfishing, and habitat degradation/water pollution. The oil found in the head is believed to have medicinal properties, and is widely available for sale in urban markets. The estimates presented at the meeting for the Ganges-Brahmaputra were 3500 population and 350 annual mortality (by Dr. Lal Mohan); for the Brahmaputra alone, 1300 population (by Ahmed and Singh). NERP field studies found 146 individuals in the Surma-Kushiyara system during the monsoon; numbers fall to between 30 and 35 in the dry season, with these concentrated in the river duars, in particular those near Tangua and Gurmar Haors. Actions to conserve the Bangladesh population were put forward by Haque (1986).

The Eurasian Otter is listed on CITES Appendix I. It is rare in Bangladesh, and is found in selected wetlands throughout the country. Globally, it is the most widely distributed otter species, ranging from Ireland to Japan and the Arctic to North Africa and Sri Lanka; within this range, ten subspecies are recognized. This wide distribution reflects the species' adaptability to a wide range of

freshwater habitat conditions, even extending to coastal areas if rainfall is sufficient to maintain freshwater pools close to shore for the animals to drink and bathe. Populations are nonetheless declining rapidly worldwide, particularly in Asia, due to habitat loss and degradation, especially from water pollution, and trapping mainly for fur. In the Northeast Region, the Eurasian Otter is now rare; their historical status is not known. Nests for breeding are most often found in older hollow hijal trees, and thus destruction of such trees is a key threat. During the NERP 1992/3 field season, signs of the species have been observed at three sites in the region (Tangua, Pasua, Hakaluki).

The Smooth Indian Otter is classified as Insufficiently Known (i.e. suspected to belong in one of the determinate categories indicating threatened status; IUCN, 1990) and is listed on CITES Appendix II (controlled trade). It is somewhat more common than the Eurasian Otter in Bangladesh, and like it is found in selected wetlands throughout the country. It is found only in tropical Asia. It is more terrestrial in habit, preferring hill forest and mangrove areas; adaptations for this include feet that are only partially webbed with rudimentary fingernail-like claws used for probing in the mud and under stones. They are social animals, which renders them more vulnerable to trapping. The population found in the Northeast Region migrates transnationally along the hill streams emptying onto the alluvial fan areas. In monsoon, they inhabit the lowest reaches of the streams in the hills in India. In the dry season, they come down to the swamp forests and reed swamps of the haor areas. During the NERP 1992/3 field season, signs of the species were found at 14 sites in the region.

A recent global action plan for otter conservation prepared under the auspices of IUCN/SSC Otter Specialist Group is presented in Foster-Turley *et al.* (1990).

Content

- Detailed baseline studies of population status, threat patterns, utilization and trade, etc. (Note linkage to Regional Water Quality Characterization).
- Guidelines for ongoing monitoring, emphasizing people's participation. (Note linkage to ongoing water quality characterization).
- Design, implement, and evaluate public awareness programs. For dolphins, targets groups would be fishermen and people living on the banks of rivers. For otters, target group would be people living near wetlands with otter habitats and populations. Investigate feasibility of public awareness program targeted to domestic consumers of dolphin oil and any other products.
- Study and if feasible implement a captive otter centre. Objectives would include breeding for reintroduction and education of fishermen and other local people to support otter species and habitat recovery and conservation.
- Recommendations for aquatic mammal measures and activities to be included in (i) fisheries sanctuary management (for dolphins) and (ii) key wetland site management plans (one for each site with otters), and reed swamp and other habitat restoration activities (for otters).

Outputs Reports/memoranda: Dolphin Baseline Study, Otter Baseline Study, Ongoing Monitoring Recommendations, Public Awareness Programs Design, Public Awareness Programs Evaluation, Captive Otter Centre Feasibility Study and Implementation Plans, Dolphin Recovery Recommendations for Fisheries Sanctuary Management, Otter Recovery Recommendations for Key Wetland Sites/Habitat Restoration (by site and habitat type).

Biophysical/social: greater public awareness; reduced commercial and other threats; more and larger populations; operational captive otter centre.

Inputs Local and expatriate project staff. Funds for public awareness materials and activities. Facilities for otter centre.

Linkages Within NEMREP: to Regional Water Quality Characterization; to Key Wetland Sites; to Swamp Forest Habitat restoration; to Reed Habitat restoration. To other proposed NERP initiatives: to Fisheries Management.

Objectives

- Find any additional surviving populations
- Stabilize or increase numbers in existing populations
- Establish additional populations if possible
- Understand and reduce commercial and other threats

Background

Four of the five extant terrestrial carnivore species (one fox and four small cats) currently found in the Northeast Region are listed as globally threatened or commercially threatened. The threatened/commercially threatened species are:

- Bengal Fox *Vulpes bengalensis* khek shial — listed as Indeterminate (known to be either Endangered, Vulnerable, or Rare; IUCN, 1990a).
- Small Indian Civet *Viverricula indica* khatash — listed on CITES Appendix II (trade controlled).
- Jungle Cat *Felis chaus* bon biral — listed on CITES Appendix II.
- Fishing Cat *Felis viverrina* mecho biral — listed on CITES Appendix II.

One other cat species, Large Indian Civet *Viverra zibetha* bagdash, is still found in the region and is not listed as either globally threatened or commercially threatened.

Two globally endangered large cats are already extinct in the region: Leopard *Panthera pardus* chita bagh and Bengal Tiger *Panthera tigris* bagh; both are Endangered (IUCN, 1990a) and listed on CITES Appendix I. These are discussed below, under the element *Large Mammal and Reptile Species*.

Threats to the remaining cats vary from species to species, but include habitat destruction, hunting for skin, and destruction of corridors between freshwater swamp forest and homestead forest. The regionally extinct cats are larger, and pressures on them would have included sport hunting, declining habitat for and populations of large ungulates, and destruction of individuals thought to engage in attacks on humans or livestock.

The Bengal Fox was once very common on the higher lands (homestead and kanda) throughout the wetlands of Bangladesh, including the Northeast Region, and has a special role in Bengali folklore and songs. The species is now restricted to areas where vegetation remains in good condition and human disturbance is relatively low, and, as these areas continue to shrink, pressures on the remaining fox populations will intensify. Also, foxes are evidently hunted to provide medicinal oils which are found for sale in all the major urban areas of Bangladesh.

Two other threatened small terrestrial mammals occur in the region, Indian Pangolin *Manis crassicaudata* bon rui and Hispid Hare *Caprolagus hispidus*

khorgosh. The pangolin appears on CITES Appendix II (trade regulated). This species is one of three Asian members of the family (Manidae) of scaly anteaters, unique among Old World mammals for their covering of horny body scales. All are highly specialized to feed on insects, basically ants and termites. The Bangladesh species is found mainly near hilly areas, particularly in bamboo thickets. It feeds by breaking into anthills, getting ants into its scales, then climbing into water whereupon the ants float up in balls and can be consumed easily. The animal is easily captured: when disturbed it curls up into a ball and can be picked up. It is threatened by hunting, mainly for its scales which are believed by some ethnic groups (in Bangladesh by practitioners of traditional medicine, kobiras, and in Asia generally by ethnic Chinese) to have medicinal value; the meat is also eaten in some cases.

The Hispid Hare or Assam Rabbit is listed as Endangered (IUCN, 1990a) and listed on CITES Appendix I (trade prohibited). This is essentially an upland species that appears rarely in the lowlands and will not be discussed further here; activities undertaken as part of Upland Biodiversity would address this and other threatened upland species.

Content

- Detailed baseline studies of population status, threat patterns, utilization and trade, etc.
- Guidelines for ongoing monitoring, emphasizing people's participation.
- Design, implement, and evaluate public awareness programmes.
- Recommendations for threatened mammal recovery measures and activities to be included in key wetland site management plans (one for each site with cats/foxes) and for habitat restorations.

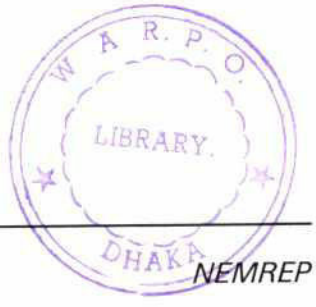
Outputs

Reports/memoranda: Baseline Study, Ongoing Monitoring Recommendations, Public Awareness Programs Design, Public Awareness Programs Evaluation, Recovery Recommendations for Key Wetland Sites/Habitat Restoration (by site and habitat type).

Biophysical/social: greater public awareness; reduced commercial and other threats; more and larger populations.

Inputs

Local and expatriate project staff. Funds for public awareness materials and activities.



COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened and Commercially Threatened Species Recovery**
ACTIVITY: ***Threatened Large Mammal and Reptile Species***

Objectives

- Develop an understanding of the biophysical and social issues involved in reintroducing, either as viable wild populations or as semi-domesticated groups, each of the nine mammal species and one large reptile species once found in the region that are now absent from it or nearly so. As appropriate, design, implement, and evaluate pilot reintroduction projects which are beneficial both from a biodiversity perspective and to local people.

Background

All but one of the region's largest mammal species are now regionally extinct. These species include the two largest cats (Leopard *Panthera pardus* and Tiger *Panthera tigris*), the three rhino species (Sumatran Rhinoceros *Didermocoeros sumatrensis*, Javan Rhinoceros *Rhinoceros sondiacus*, and Great Indian Rhinoceros *Rhinoceros unicornis*), three ungulates (Gaur *Bos gaurus*, Pygmy Hog *Sus salvinius*, and Wild Buffalo *Bubalus bubalis*; the latter survives in domestication, however). The species in this group share some similar factors leading to their regional extinction: conversion of reed swamp and grass land habitats to rice cultivation; hunting for subsistence, sport, and/or commercial reasons, as well as in response to direct conflicts with humans (for the predators, primarily attacks on livestock and humans; for the rhinoceroses and ungulates, primarily crop damage).

The only large mammal species still occurring in a wild state in the region is Asian Elephant *Elephas maximus*. Regional populations are limited to a few individual elephants and small bands which still migrate transnationally between summer upland habitat in India and winter lowland habitat in Bangladesh. A number of domesticated elephants are present, employed for heavy work in forestry and other pursuits and for as commercial entertainment in roadside shows. Species recovery for the elephant would amount to locally-based measures to conserve and enhance habitats used by existing populations and to manage elephant-human interactions, and possibly reintroduction of the elephant into additional areas. An important issue is the protection and reestablishment of corridors between upland and lowland habitats used by the species.

All the above species are listed as globally threatened in the RDB: the Gaur is listed as Vulnerable, and the rest as Endangered.

One reptile species, Marsh Crocodile *Crocodylus palustris*, has also disappeared from the region. It is listed as Vulnerable and trade in the species is prohibited (CITES, Appendix I). The skin of this species is valued in the manufacture of handbags, suitcases, and the like, as it is relatively large, thick, durable, and has attractive markings. Also, the carbonized bones were used in the manufacture of perfumes for fixing scents. It became extinct from the wild in Bangladesh in the late 1950s as a result of commercial overexploitation. A few semi-domesticated individuals survive in Bangladesh in the National Zoo in Dhaka and

as shrine animals in Bagerhat. Recovery programs for this species are underway in Nepal at Royal Chitwan National Park, and in Madras in India. Commercial farms exist in Thailand and possibly in other countries. The outputs can be traded internationally only in contravention of the CITES ban, however. At present, this would preclude establishment of commercial farming of this species in Bangladesh.

Rock Python *Python molurus molurus*, listed as Vulnerable in the RDB and on CITES Appendix I, has recently been reported in the region, but NERP did not find any evidence of it.

A common characteristic of most or all of the animal species mentioned above is their potential drawing power for domestic and international ecotourism. At the present time, it may seem farfetched to suggest that any of these species could be reintroduced as part of an overall programme to generate rural and regional income and foreign exchange through environmentally sustainable tourism. With rapidly rising domestic and regional incomes over the next decades, however, the balance of benefits and costs may change quickly.

In terms of biodiversity conservation (i.e. preventing species extinctions), a strong argument for reintroduction comes from studies of extinction probabilities for threatened species which suggest that a species' probability of extinction is more sensitive to the number of separate populations than to the number of individuals holding the number of populations fixed (Shaffer, 1987).

Content Investigate the considerations governing feasibility of reintroducing the species discussed above. If appropriate, design, implement, and evaluate pilot reintroduction projects.

Outputs Reports/memoranda: Reintroduction Study Report. Pilot Reintroduction Project(s) Design(s), Implementation Plan(s), and Evaluation(s).

Biophysical/social: if appropriate, reintroduced populations managed with appropriate local input.

Inputs Local and expatriate project staff. If appropriate, reintroduction project facilities.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened and Commercially Threatened Species**
ACTIVITY: ***Freshwater Turtles***

Objectives

For all of the threatened turtle species of the Northeast Region,

- Stabilize or increase numbers in the known turtle populations
- Find additional surviving populations of the species which are uncommon, scarce, or rare, in the region and globally, and stabilize/increase numbers in these populations
- Establish additional populations of rare or endangered turtles
- Reduce commercial threats to all turtles
- Promote turtle farming as an economic activity, if economically and socially feasible models can be developed (see also *Reptile and Amphibian Farming* below)

Background

Turtles are a particularly vulnerable group, with many species of conservation concern worldwide. In Asia, turtles are threatened by habitat destruction, subsistence and commercial exploitation, and by deterioration of water quality. The commoner species of turtles are or could be a significant economic resource, if managed sustainably; also, protection of the more vulnerable species would be made easier by strong populations of the more common species.

Currently, global turtle conservation actions are guided by the action plan for tortoise and freshwater turtle conservation prepared by the Tortoise and Freshwater Turtle Specialist Group of the Species Survival Commission (IUCN, 1989). In South Asia, the most aggressive turtle conservation efforts so far have been carried out in India, mainly driven by strong government commitment and strong governmental and non-governmental institutional structures for conservation, in collaboration with international conservation organizations and researchers, supported by some external financial assistance. In Bangladesh, some surveys of trade and wild populations, including those under NERP, have been undertaken, but species protection, regulation of trade, improved enforcement of wildlife laws, and so on are still in the early stages.

The threatened turtle species of in the Northeast Region, in descending order of NERP's assessment of their global vulnerability, are:

Sylhet Roof Turtle *Kachuga sylhetensis*. This is one of six or more of poorly known localized endemic Asian turtle species identified in the IUCN/SSC conservation action plan for tortoises and turtles (Stubbs, 1989) as in need of special study, because "it is unlikely that these species can easily be incorporated into other major turtle or tortoise projects in the [Indomalayan] region . . . [due to] their isolated localities." No populations are currently known in the Northeast Region. The total range is Bangladesh and parts of India. The most recent evidence for this species in the region is a shell brought to Dhaka University that was reportedly found in somewhere in Sylhet in 1983. Current (IUCN, 1990a)

global status is Indeterminate; this will be changed to Rare in next edition of the Red Data Book.

Narrow-headed Soft Shell Turtle *Chitra indica*. The most recent sighting in the region was in 1989 of a very young juvenile in the Old Brahmaputra River near Gaffargaon. No populations have yet been located in the Northeast Region. The total range is all of South and Southeast Asia, usually inhabiting deeper areas of rivers. This species is believed by the NERP team to be threatened; its absence from the current (1990) and forthcoming editions of the RDB, and from the CITES Appendices are believed to reflect an oversight.

Malayan Box Turtle *Cuora ambionensis*. The most recent sighting in the Northeast Region was in 1987 near Companiganj. No populations have yet been located in the region. The total range is South and Southeast Asia, Indonesia, and the Phillipines; there is some thought that this is really more than one species. It prefers deeper rivers and river bottoms. Currently (IUCN, 1990a) the species is not identified as threatened; this will changed to commercially threatened (a new category) in the next edition of RDB. It is not listed in the CITES Appendices.

Ganges Soft Shell *Aspideretes gangeticus*. This species is found in the larger rivers; it nests on sandy banks during September-December. It is distributed throughout the Indian subcontinent. This once very common species is heavily exploitated for both local consumption and export and as a result is now uncommon. It is listed on CITES Appendix I.

Spotted Pond Turtle *Geoclemys hamiltoni*. This species is evidently highly dependent upon reed community habitat, which in the Northeast Region is itself threatened. The total range is India, Bangladesh, and Pakistan. Only one population is known in the Northeast Region, at Pasua Beel, Gurmar Haor; ten shells were obtained by NERP in 1992-3 from local people who had caught and consumed the animals. Current (IUCN, 1990a) global status is Indeterminate; this will be changed to Vulnerable in next edition of the RDB. Trade is prohibited, as it is listed on Appendix I of CITES.

Bengal Eyed Turtle *Morenia petersi*. This turtle is endemic to the eastern part of the Ganges and the western part of the Brahmaputra deltas; it may be abundant in certain localities. Species is semi-aquatic, inhabiting rivers and standing water. In the Northeast Region, two populations are known, at Meda Beel near Kalumakanda and at Hail Haor. Currently (IUCN, 1990a) the species is not identified as threatened; this will changed to commercially threatened (a new category) in the next edition of RDB. It is not listed in the CITES Appendices.

Brahminy Turtle *Hardella thurjii*. In the Northeast Region, three populations are known, at two locations in Tangua Haor and one in Pasua Beel, Gurmar Haor. The total range is Bangladesh, India, and Pakistan. It prefers still or sluggish water. Exploitation and disturbance have extirpated populations from some areas in southwestern Bangladesh, but healthy populations still exist in other areas. This species is not listed in the RDB nor in the CITES Appendices, and no changes in status are planned.

Peacock Soft Shell Turtle *Aspideretes hurum*. Widespread in the northern Indian subcontinent and found in a variety of habitats. One of the most exploited species of freshwater turtle in Bangladesh; large numbers are exported, even though trade is currently prohibited (species is listed on CITES Appendix I). The status will be changed to allow regulated trade (species will be moved to CITES Appendix II soon).

Flapshelled Spotted Turtle *Lissemys punctata*. Widespread in the Indian subcontinent, extremely adaptable and capable of surviving in a very adverse conditions including areas modified by human activities. One of the most exploited species in Bangladesh. Feasibility of farming is a possibility. Currently listed on CITES Appendix I; will be shifted to Appendix II.

Common Roof Turtle *Kachuga tecta*. Widespread and common in the Indian subcontinent. Prefers standing or sluggish water. Seldom exploited for food as it is too small; some may be exported for the pet trade in the West. Currently listed on CITES Appendix I; will be shifted to Appendix II.

Content

- Captive breeding
- Informal education for residents living near turtle populations/habitats.
- Small scale habitat enhancement or restoration
- Field research to find additional populations; to monitor known populations; to guide conservation efforts
- Formal training in turtle identification for customs officers and Forest Department officials involved in CITES enforcement.
- Implement needed changes needed to Wildlife Act.
- Conference with local, regional, and international academics
- Graduate studies with local candidates
- Promotion of turtle farming as an economic activity, if feasible models can be developed

Outputs

Reports/memoranda: Baseline Study, Public Awareness Activities Design, Public Awareness Activities Evaluation, Recovery Recommendations for Key Wetland Sites/Habitat Restoration (by site and habitat type), Conference Proceedings

Biophysical/social: greater public awareness; reduced commercial and other threats; more and larger populations; captive breeding centre.

Inputs Local and expatriate project staff. Funds for public awareness materials and activities. Captive breeding facilities.

Linkages With Reed Habitat Restoration, Key Wetland Sites, and Biodiversity Strategic Planning.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened and Commercially Threatened Species**
ACTIVITY: ***Reptile and Amphibian Farming***

Objectives

- Develop and test models for commercial farming of reptiles and amphibians
- Work with private sector to design and test a system for recruiting and supporting new farmers

Background

A proposal for an ambitious private multi-species farming complex was circulated in 1992 by a group of Bangladeshi wildlife biologists and entreprenuers (Husain *et al.*, 1992). Though the project has not yet moved forward, the idea is intriguing and parallels projects already under way in other tropical countries.

The international demand for reptile and amphibian food, skin, and other products is strong. Demand is likely to grow rapidly over the next decades; among other things, an important market is China, where personal incomes are expected to grow rapidly over the coming decades. Other important markets include Europe and America (frog legs), Japan (lizard skins), and overseas Chinese communities in Asia and elsewhere.

Competitive advantage in this market likely depends on many factors: biophysical conditions (climate etc.); land, labour, and other input costs; local markets for any intermediate products; trade links to importing countries; and so on. It is at least possible that Bangladesh in general, and the Northeast Region in particular, would be potentially competitive producers. Many commercially important reptile and amphibian species flourish(ed) in the wild here. Input costs, specifically labour, are not the lowest in the world (Vietnam's are lower, for example), but compare favourably with other countries such as Thailand already engaging in such farming. Local markets for intermediate products (waste for organic fertilizer, poultry or fish feed) exist. And trade in such products is clearly well-established and of long standing, given that enormous quantities of wild reptiles and amphibians have been exported over the last few decades — enough to extirpate some species from parts of the country.

All reptile and amphibian species native to the region would be potential candidates for farming, whether currently listed as threatened/commercially threatened or not. Species listed on CITES Appendix I cannot currently be traded. Development of pilot farms for such species could still serve licit objectives: local release of output would replenish wild stocks, and CITES listings do change as species status and trading conditions change.

Misrepresentation of wild-source material as farm-source is a key problem, and methods used in other countries to minimize this need to be studied very closely. There should probably also be some provision for a certain percentage of farmed individuals to be released into the wild to replenish wild stocks already in decline due to previous commercial exploitation; this could be a condition for export licensing, for example.

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Reptile and amphibian farming *continued*

Current Bangladesh trade in wild species includes important amounts of monitor lizard skins (Bengal Grey Lizard *Varanus bengalensis* and Yellow Common Lizard *Varanus flavescens*) and frog (Bull Frog *Rana tigrina* legs), though prohibited by Bangladesh law, and listed under CITES (lizards Appendix I; frog Appendix II. The Yellow Common Lizard is also listed in the RDB as Indeterminate (known to be either Endangered, Vulnerable, or Rare).

Commercial trade in the two monitor lizard species is mostly with Japan. Japan, though a party to CITES, has designated the lizards as outside the terms of their accession to the agreement to protect Japanese handbag manufacturers. Though monitor lizard exports were prohibited by Bangladesh in 1985, the Trade Records Analysis of Flora and Fauna in Commerce (TRAFFIC), Japan branch, found from trade records in Japan that over 89,042 kg of monitor lizard skins (corresponding to about 1.8 million lizards) had been imported into Japan between 1986 and February 1990, mostly labelled upon export from Bangladesh as "dried fish" or other products and relabelled correctly immediately before entry into Japan (*Mainichi Daily News*, 1990).

Content

Investigate feasibility of reptile and/or amphibian farming in the Northeast Region in particular, and Bangladesh in general. This would involve collecting information on such activities in other countries in the region; on the trade in wild species from Bangladesh; analysis of legal (CITES, Wildlife Protection Act) and other constraints; and so on. While investigations of the feasibility of large-scale farms are not precluded (these also generate employment, rural and regional income, and foreign exchange, and possibly take some pressure off wild stocks), emphasis would be on small-scale farming that would be accessible to individuals or small cooperatives of relatively modest means. The role of the public sector in this type of farming would be limited to extension, policy, legal, extension, credit, and other support.

If plausible small-scale models can be devised, pilot demonstration farms would be set up and, if successful, a small extension programme carried out.

Outputs

Reports/memoranda: Reptile/Amphibian Farming Specialist Study; Feasibility Study describing one or more feasible farm models). Pilot Farm: Design; Operations Manual; Evaluation. Demonstration Programme: Plan; Evaluation.

Inputs

Local and expatriate project staff. Pilot farm facilities. Demonstration programme expenses for materials, travel allowances, etc.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened and Commercially Threatened Species**
ACTIVITY: ***Bengal Rose***

Objectives

- Obtain baseline information about the current regional and global status of this indigenous species.
- Stabilize existing populations which are restricted to some of the large haors of northern Sunamganj.
- Establish additional populations in the key wetland sites and possibly other areas; a possible use of this large thorny inundation-tolerant plant is as a fishing preventer in fish sanctuaries
- Explore species' commercial potential as an inundation tolerant rose species, to enhance *ex situ* conservation and generate income

Background

Bengal Rose is an indigenous rose species of the Indian sub-continent. The genus *Rosa* is represented globally by more than 150 species, but Bangladesh has only this one endemic species. Bengal Rose is a woody shrub with all the characteristics of this genus, growing as tall as 2 m, unique among *Rosa* for its tolerance of prolonged waterlogging. This property is of interest to rose breeders in the production of inundation-tolerant rose varieties.

The previous extent of the species was from Assam through Bangladesh up to the semi-arid region of Bihar, with its greatest abundance in freshwater swamps of the Assam-Sylhet area. Habitat destruction, especially the eradication of reed swamps has made it vulnerable to extinction. The species is already extinct from West Bengal and Bihar, and from the northwestern region of Bangladesh west of the Jamuna. The only remaining populations are now found in some haor areas of northern Sunamganj district. The most healthy known population is at Tangua Haor (NERP field observation 1993); other remnant populations are located nearby. The species has been the subject of international scientific interest and joint field studies involving Indian and Bangladeshi scientists.

Content

- Collection of baseline information about the current status of this plant.
- Identification of suitable areas for rehabilitation.
- Development of multiplication and habitat restoration technique.
- Preparation of nurseries and test plot.
- Investigation of commercial significance as a genetic resource for developing inundation resistant rose varieties.

Outputs

Sustainable healthy populations. Field research reports, including baseline data and recommendations for commercial exploitation.

Inputs

Local and expatriate project staff.

Linkages

Within NEMREP: Reed Habitat restoration and Key Wetland Sites. To other NERP proposed initiatives: Fisheries Management.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Threatened and Commercially Threatened Species**
ACTIVITY: ***Eurayle ferox***

Objectives

- Obtain baseline information about the prevailing regional status of this species
- Stabilize and increase the known natural populations in the Northeast Region of Bangladesh
- Investigate causes and rate of depletion and possible mitigating measures.
- Explore culture potential, to create sustainable supplies to meet market demand, thereby reducing pressures on natural populations

Background

Eurayle ferox makna is the largest member of the family Nymphaceae. It is a rooted floating plant having large round floating leaves. The entire body is covered with spines, including the fruits. The flowers are violet and less conspicuous than those of other Nymphaeas.

The range of this species is from Kashmir across Bangladesh up to China. It has always been observed to be much less abundant than other similar species, and over recent decades, populations throughout Bangladesh were observed to decline. The reasons for this are basically not known, but harvesting of the fruit as a food starch and for medicinal purposes is suspected. In the Northeast Region, the species is currently found at only three sites. The largest and healthiest population is found in Hail Haor; smaller numbers are found in Hakaluki Haor and Morir Haor.

In India, from Bihar to Uttar Pradesh, the species is found in many ponds in mixed culture with fish; the fruits are harvested for consumption, and the masses of spiny plants deter illicit fishing. If a similar type of culture is biophysically and socially feasible in the Northeast Region, it would reduce harvesting pressure on wild populations.

Content

- Collection of baseline information about the current regional status of this plant, including Investigation of possible cause of depletion, including chemical tests of soil and water around and away from existing populations
- Identification of areas suitable for rehabilitation
- Investigate potential for pond culture; food value of seeds
- Development of plantation techniques for natural and culture conditions

Outputs Reports/memoranda and biophysical/social outputs.

Inputs Local and expatriate project staff.

Linkages Within NEMREP: to Key Wetland Sites. To other NERP initiatives: to Pond Aquaculture.

COMPONENT: **BIODIVERSITY**
ELEMENT: **Upland Biodiversity**

Location Uplands of the Sylhet and Mymensingh Forest Department Ranges, plus transnational upland areas adjacent to the region

Area Regional/Transnational

Objectives To characterize and undertake necessary measures to conserve the biodiversity of the region's upland areas, taking into account the needs of local people dependent on these areas. To support the development of transnational arrangements for enhancement and management of upland biodiversity and transnationally (India upland — Bangladesh lowland) migrating species.

Background Some parts of the region's upland areas, principally those on Forest Department land, have some ecological character as natural forest ecosystems. As such, they are important national biodiversity havens, for purely upland species and for some species which migrate locally between upland and lowland/wetland areas. The Rema-Kalenga Wildlife Sanctuary, established in 1981, contains the last remaining patch (1,036 ha) of primary forest in the Sylhet region (IUCN, 1990b).

There is a need to survey these areas to determine what biodiversity assets are present; these would include, but are not limited to, threatened ecosystems, habitats, ecological communities, and species. Once these assets are identified, management systems to safeguard and enhance them will have to be designed and implemented, in partnership with relevant interested parties. Options such as leasing out Government/Forest Department-owned areas to a nature conservancy trust, possibly under NEMREC or in association with it, should be explored. The interests of local groups or individuals dependent upon forest access and products must be protected, and they should be fully involved in planning and management.

Content

- Baseline surveys with the purpose of providing the basis for informed decisions on the best use of these areas. Biodiversity assets would be identified and characterized
- Interagency and public consultations leading to management plans to achieve best use of each area, given realistic constraints
- Investigate management/recovery options for each type of key biodiversity asset
- Feasibility study/detailed design and initial set-up of improved management systems, including measures to manage/rehabilitate key biodiversity assets. Rema-Kalenga Sanctuary would be carefully surveyed and management upgraded to a level in keeping with its national significance.

Outputs	Reports/memoranda: Upland Areas Study; Consultations Report; Improved Management Systems Design. Biophysical/social: Management Systems Implementation.
Inputs	Local and expatriate project staff. If areas leased to nature conservancy trust through/with NEMREC, financing will be necessary.

COMPONENT: **SURFACE WATER QUALITY MANAGEMENT**

The Surface Water Quality Management component is composed of four elements:

- Regional water quality characterization
- Pulp and paper mill effluent treatment
- Industrial pollution abatement at smaller facilities
- Duckweed-based domestic wastewater treatment

Objectives

General — Provide information needed to make decisions about structural and non-structural water quality management measures. Such measures include structural elements such as rural water seal latrine programs, urban sewage treatment systems, industrial pollution abatement systems, and non-structural elements such as educational programmes to promote tube well drinking water or improved factory housekeeping in selected industries.

Specific —

- To screen regional water quality and establish a two-year baseline data set, for:
  - — Representative beels and ponds
  - — Major and selected minor rivers entering and leaving the region
  - — Selected industrial effluent streams and receiving waters,

  focusing on parameters of interest to public health, agriculture, fisheries, and wetland resources
- To prepare operational plans for appropriate ongoing (year three and beyond) water quality monitoring in the Region

Background

The goal of water quality characterization is to provide decision-makers with the information they need to make decisions about water quality management measures. Such measures would include infrastructure investments (rural waterseal latrine programs, urban sewage treatment systems, industrial pollution abatement systems), as well as non-structural elements (educational programs to promote tube well drinking water or improvements in factory housekeeping in selected industries).

How do water quality data contribute to this goal? There are several ways:

- By allowing hypotheses about the impacts of poor water quality, and by extension, the impacts of efforts to improve it, to be tested. For example, pollution from one of the region's most significant pollution sources, the Sylhet Pulp and Paper Mill at Chhatak, is thought by fishermen to affect the openwater fishery in the Surma, as far down as Khaliajuri. This hypothesis cannot yet be evaluated because water quality data is currently available only from one sampling station near Chhatak and even at this station several parameters of interest have not been measured. Another example is a correlation between fish ulcerative disease prevalence and beel water quality noted in the *Fisheries Specialist Study* and by others; again the necessary measurements are lacking.
- By allowing the relative significance of different pollution sources to be characterized. For example, many different pesticides (legal and illegal) are in use in Bangladesh. Water quality data can help to focus enforcement and education efforts on the chemicals of greatest public health or environmental concern.

- By providing advance warning of unacceptable trends in water quality. Urbanization, industrialization, and pesticide use are all expected to increase markedly over the next decade in Bangladesh. Monitoring trends in water quality parameters will help decision-makers to intervene in a timely manner to avert damage to public health, fisheries, agriculture, and wetland resources.

The sampling strategy — where, when, how often, for how long A key point is that, for the goal of water quality characterization to be achieved in a cost-effective manner, water quality measurement programs must be user-driven.

A opportunity now exists, as prices for microprocessor-based water quality analysis field equipment continue to fall, to undertake cost-effective and decentralized water quality monitoring.[5] Such an approach has many advantages:

- Overall higher efficiency (data collected per unit cost) than laboratory methods, while providing adequate accuracy
- Reduces problems with sample contamination and spoilage, by eliminating the need for samples to be transported quickly and under proper ambient conditions (refrigeration) from field to lab
- Allows new sample sites to be screened and assessed on the spot
- Facilitates the selection of samples for further laboratory analyses
- Provides water quality chemists immediate feedback — information can be validated immediately; can be very important in terms of on-the-job learning and professional motivation
- Does not require staff highly trained in particular laboratory analysis methods — general competence in chemistry is adequate

For some parameters of interest, such as microbiological parameters and biological oxygen demand, field methods must be supplemented with laboratory-based tests.

Content

The project would, under the ongoing guidance of water quality managers from across the range of relevant institutions, generate a baseline data set on regional water quality through the use of field-based analysis augmented with laboratory tests. Equipment and appropriately trained staff would be assembled; sampling points established and documented; river monitoring undertaken in dry (winter) and monsoon (summer) seasons; selected beels monitored (since they are an important component of fisheries and the key wetland sites); representative ponds used for aquaculture and domestic purposes monitored; data analyzed and interpreted; and an ongoing monitoring program designed.

[5]DOE water quality monitoring has so far relied on laboratory methods of analysis and on in-house laboratory facilities, with supplemental capabilities provided by labs at Bangladesh University of Engineering Technology and at the Atomic Energy Commission.

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Regional water quality characterization *continued*

The Project would generate a baseline data set on regional water quality, through the use of field-based analysis augmented with laboratory tests. Activities:

- *Procure equipment, mobilize and train staff.* Team would consist of four full-time chemists or chemical engineers with Masters-level qualifications.
- *Assess proposed sampling points.* Field visits and trial measurements to proposed sampling points.
- *Prepare monitoring manual.* Document final sampling sites, schedule, parameters to be measures, sampling procedures, data capture formats.
- *Dry season river monitoring.* Dry season (December to April) flow accounts for less than 5% of total annual flow, thus water quality in rivers receiving pollution is subject to serious deterioration. Sampling would focus on points near key pollution sources such as Sylhet Pulp and Paper Mill; Sylhet town; Mymensingh town; industrialized areas on the Lakhya River; plus Bhairab Bazar to characterize total regional output. Parameters to be monitored are shown in Table 6.5.
- *Monsoon season river monitoring.* Of interest in the wet season is the flux of materials (salts, nutrients, sediments) through the region. Local sources of pollution are of much less importance at this time as dilution volumes are very high. Sampling would focus on input to the Northeast Region from upstream catchments in India; these contribute 60% of the total regional outflow. Parameters to be monitored are shown in Table 6.5.
- *Beel and pond monitoring.* Beels are an important component of the openwater fishery and of key wetland sites. Beel water quality is thought to be deteriorating generally, as a result of increasing use of pesticides and fertilizers, increasing abstraction of irrigation water, and the changing character of aquatic and semi-aquatic vegetation communities (particularly reed swamp) which when relatively intact support water purification functions. Ponds are a key component of the village landscape, as multi-use water sources and waste sinks. Sampling would focus on a suite of sites selected to be representative of the range of beel/pond conditions in the region.
- *Data analysis and interpretation and as-needed modifications of monitoring program.* A total of two years of field monitoring would be undertaken. For each monitoring activity (dry season river, wet season river, beels and ponds), near the end of the first and second year's sample period, the assembled data set would be analyzed and interpreted, and any needed modifications to the program documented.

The proposed set of main monitoring sites, and other detailed information, are documented in an internal NERP report (Pineau, 1992).

Outputs Regional Water Quality Characterization Interim and Final Reports. Data reports and computer files. Recommendations for ongoing water quality monitoring.

Inputs

Local and expatriate project staff.

The general type of field equipment required, parameters measured, and price ranges would be:

- *Field lab* (US$5500). Includes spectrophotometer, pH meter, conductivity and total dissolved solids meter, reagents and apparatus. Measures (among other things) pH, conductivity, total dissolved solids, alkalinity, carbon dioxide, hardness (calcium and magnesium as carbonates), calcium, potassium, manganese, total iron, silica, chloride, sulfate, nitrate, ammonia, total phosphorus, cadmium, total and hexavalent chromium, lead, nickel, and zinc.
- *Dissolved oxygen meter* (US$1500).
- *Ion-selective electrode meter* (US$800).
- *Chemical oxygen demand (COD) test system* (US$1000).
- *Field portable gas chromatograph* (US$23,000). Used for the determination of volatile organic compounds, pesticides, and other organic contaminants.

Linkages

To the national level through the Surface Water Quality Strategic Planning; to NEMREC.

Table 6.5: Parameters to be monitored

Parameter	Type	Existing	Proposed					
		DOE river sites (n=5)	Rivers		Beels and ponds (n=6)	Effluents (n=1)	Analysis method	
			Dry season (n=8)	Wet season (n=6)			Field lab	Other/notes
Alkalinity			x	x			x	
Biological oxygen demand (BOD)		x	x					Off-site
Chemical oxygen demand (COD)			x					COD test system
Chloride		x	x				x	
Conductivity			x	x				Cond/TDS meter
Dissolved oxygen (DO)		x	x					DO meter
Hardness			x	x			x	
Heavy metals			x				x	Cr, Cd, Pb (what about Hg, others?)
Major anions (Ca, Mg, Na, K)			x	x				Electrode meter
Major cations (Cl, SO_4)			x	x				Electrode meter
Nutrients (nitrate, ammonia, phosphorus)			x	x	x		x	
Pathogens/fecal coliforms			x					??off-site
Pesticides					x			Field gas chromatograph
Ph		x	x	x			x	
Silica				x			x	
Suspended solids				x				??
Temperature			x					??Digital thermometer
Total dissolved solids (TDS)			x	x				??
Total solids (TS)		x						??
Turbidity		x						??Secchi disk

COMPONENT: **SURFACE WATER QUALITY**
ELEMENT: **Pulp and Paper Mill Effluent Treatment**

Location Surma River at Chhatak

Area Surma River downstream of Chhatak

Objectives To reduce significantly negative impacts from discharge to the Surma River of the Sylhet Pulp and Paper Mill effluent. These impacts include damage to open water fisheries production, contamination of fish flesh, and other short- and long-term negative impacts to the biophysical environment and to human health. In addition, this would be a pilot project and training exercise which if successful would lead to improved effluent treatment at all other pulp and paper mills in the country.

- To provide training to selected personnel of BCIC, DOE, and the private sector (industry personnel, academic chemists and engineers, pollution control consultants) in appropriate clean process and industrial pollution control topics, using SPPM as a case study
- To undertake pre-feasibility studies of pollution control at other existing and planned pulp and paper mills

Background In the Northeast Region, the Sylhet Pulp and Paper Mill at Chhatak is currently the most significant single source of industrial pollution.[6] SPPM, which began production in 1976, uses a bleached Kraft process with a design capacity of 100 air-dried tonnes per day. Actual production is 30 to 80 ADT/d due to shortage of input materials. SPPM's 1991 annual gross value added (economic) was US$3 million.

Existing treatment facilities consist of two lagoons in series. Observed poor removal of suspended solids and no removal of BOD suggests that they are unaerated settling basins only.

The estimated actual effluent flow rate is 30,000 m^3/d (0.4 m^3/s). Contaminants discharged into the river reportedly include BOD of 6100 kg/d, suspended solids 6000 kg/d, mercury 1 kg/d, plus unknown amounts of AOX, dioxins, and furans which are characteristic Kraft process effluents. Presumably, contaminant discharge would increase should the gap between actual production and design capacity close; an increase in input materials would make this possible (see Reed Habitat restoration and Management). Lean season flow in the Surma is roughly 40 m^3/s (estimated from gauge measurements of 23 m^3/s at Sylhet plus estimated inflow from the three tributaries between Sylhet and Chhatak).

[6]Of 55 'main polluting industries' in Bangladesh, three are in the Northeast Region (DOE, Jun 90 report; in Bengali, 155 pp.). These are the Fenchuganj fertilizer factory, which is scheduled to close permanently in December 1993 (another fertilizer factory is planned for the area); Sylhet Pulp and Paper Mill; and the GOB-owned Chhatak cement factory. The cement factory is perhaps included for reasons of air pollution.

Locally reported impacts of the discharge include contamination of fish flesh; contamination of Surma water such that it is unfit for domestic use; and negative impacts on all living organisms in the water and on the embankment during the dry season. Fish down the river to Khaliajuri are reported to have a bad chemical odour and taste. Local people refuse to eat this fish; some is sold in Sylhet and in Dhaka at a discount of about 50%. The annual economic cost of fish production foregone from the most directly impacted fisheries unit only, the Chhatak-Sunamganj reach of the Surma, is an estimated US$10,000.[7] Total fish value may be much greater than this: the value of lost river fish production further up- and downstream, and lost floodplain and beel production in habitats linked to the river cannot be estimated from the data available. Full documentation of fisheries and other impacts would require a formal impact assessment, but this is probably not warranted. The impacts of this type of effluent are, in general terms, well known.

Treatment options for mill effluent would include: (i) upgrading the existing lagoons, (ii) upgrading plus constructed wetlands, (iii) replacement of existing lagoons with a new treatment system. A key parameter will be the marginal cost as contamination levels decrease. Put in simple terms, costs to reduce contaminant discharge from 100% to 50% can be of the same order as costs to reduce further from 50% to 40%. There is a need to define acceptable incremental compliance based on input from local residents, Government, technical experts, and facility owners. Dictating standards from above, without any flexibility to reflect local biophysical, social, economic, and political circumstances will be counterproductive, if the required level of abatement is so high that the necessary measures are unaffordable, and as a result nothing whatever is done.

The SPPM treatment abatement activity provides an opportunity for technology transfer in the area of clean process design and industrial pollution control. This activity would be cost-effective, taking advantage of the existing SPPM feasibility study technical team of expatriate and local pollution abatement experts, and would allow timely dissemination of lessons learned from the SPPM study.

Also, there are a number of other existing and planned pulp and paper facilities (four BCIC, one existing and one planned private, one existing and one planned BCIC-private joint venture), using similar processes, producing similar effluents, and with similar levels of existing treatment. As an economy of scale, and recognizing that all the existing facilities are listed among the 55 main industrial polluters nationally (DOE, 1991a), there would be an opportunity at the time of

[7]Estimate based on the difference between annual economic fish production value in the Chhatak to Sunamganj reach of the Surma (2500 kg @ Tk 30 * 0.9 economic/financial) and estimated regional average (9400 kg @ Tk 60 * 0.9) (NERP Fisheries Specialist Study, 1993; p. 93).

a SPPM study to examine these other facilities as well. If suitable, these could be used in case study projects in the training activity.

It should be noted that 1993 Forestry Master Plan strategies in pulp and paper include "requir[ing] any new mill and all major mill upgrades to install much improved pollution control equipment according to defined and appropriate standards." No reason is given for excluding existing facilities from this requirement.

Content

This initiative would consist of the preparation of a feasibility study for the treatment of Sylhet Pulp and Paper Mill effluent; the design and construction of appropriate treatment facilities; and the provision of training for mill staff in the proper operation and maintenance of treatment facilities provided. In addition, there would be additional studies and training using SPPM as a model, addressing the need for improved effluent treatment at other government- and private-owned pulp and paper mills in the country:

- Prepare a feasibility study of improved treatment of the Sylhet Pulp and Paper Mill effluents
- Design and construct appropriate treatment facilities at SPPM
- Train mill staff in the proper operation and maintenance of treatment facilities provided
- Training activities.
- Pre-feasibility studies of all or selected existing and planned pulp and paper mills.

Outputs

Report/memoranda: Feasibility Study; Detailed Design; constructed treatment facilities; SPPM staff trained in O&M. Training: Plan, Evaluation. Pre-feasibility studies for other mills.

Inputs

SPPM —

Capital costs	
Feasibility study[8]	US$200,000 ± 100,000
Treatment facility[9]	US$1.8 million ± 0.9 million
Subtotal, capital costs	US$2.0 million ± 1.0 million
Recurrent costs (O&M etc)[10]	US$50,000 ± 20,000
TOTAL ANNUAL COST[11]	US$270,000 ± 130,000

Training, pre-feasibility studies: expatriate and local pollution abatement specialists; training allowances; logistical and administrative support.

Linkages

Within NEMREP: to Reed Habitat restoration and Management; and to Regional Water Quality Characterization.

Assumptions

Pollution abatement at SPPM, an existing pulp facility, is accepted as a regional and national priority. The costs and benefits of treatment are acceptable to all concerned parties (BCIC, DOE, local residents, etc). For training and pre-feasibility studies: continuing GOB commitment to industrial pollution control; support for consideration of pollution abatement at other existing pulp and paper facilities.

[8]Based on a 20 week study involving two Canadian experts @ US$20k/person-month. Local staff costs estimated at 10% of expat costs. Economic cost 100% of financial cost.

[9]Implementation cost estimated as ten times study cost. Economic cost of implementation estimated at 90% of financial cost.

[10]Recurrent costs estimated as for two full-time Bangladeshi professionals @ US$2,000/person-month. Economic cost for skilled labour is 100% of financial cost.

[11]For all project costs, assuming financing at 12% for 30 years.

Objectives

- To maintain, in cooperation with DOE, an up-to-date inventory of regional industries releasing effluent into the air and water, and to characterize the most significant sources of impacts.

- To work with existing industries and industrial planners, through education, technical support, demonstration projects, and the like, to implement the maximum gains achievable through, as a first step, minimal and inexpensive measures such as improved plant housekeeping and controlled discharges.

Larger industrial facilities producing regionally significant pollution merit site-specific consideration. The only such facility at present is Sylhet Pulp and Paper Mill, which is covered by *Pulp and Paper Mill Effluent Treatment* initiative.

Background DOE past and planned industrial pollution control measures have mainly focused on monitoring and enforcement-related activities, such as river water sampling, generating an inventory of polluting industries, registering new industrial facilities, and the like. Though the agency has been successful in a number of areas, its staff and revenue base have always fallen short of what would be required to implement its stated programs effectively.

Content There is a need for innovative approaches based on cooperation with industry, focusing on helping industry owners and managers to move towards compliance with national pollution control standards. Means to this end would include education, technical support, demonstration projects, and the like. As a first step, the maximum gains achievable through minimal, inexpensive measures emphasizing low- and medium technology (improved plant housekeeping, controlled discharges, and the like) should be sought. Close communication with industry and development of mutual respect and trust, emphasizing gradual improvement, would be needed.

Outputs Reports/memoranda and biophysical/social.

Inputs Local and expatriate project staff.

Location All regional major urban centres, some *thana*/smaller centre, some rural villages

Population Impacted 1.6 million, major urban centres; plus some *thana*/smaller centre and rural populations

Objectives To reduce adverse health impacts associated with inadequately treated human waste while generating fish food in support of aquaculture production.

Background The floating aquatic plants with the greatest known potential for wastewater treatment include water hyacinths, duckweeds, pennywort, and water ferns.

Water hyacinth systems are capable of removing high levels of biochemical oxygen demand (BOD), suspended solids (SS), metals and nitrogen, and removing significant levels of trace elements. Hyacinths on the water surface of a pond create a totally different environmental condition in the water as compared to an exposed water surface. The dense canopy of leaves shades the surface and prevents algal growth, the near surface water tends to be low in oxygen and the benthic zone is usually anaerobic even in shallow ponds.

Duckweed systems are capable of removing high levels of BOD and SS and removing a significant level of metal and nutrients. As compared to hyacinths, the duckweed plants play a less direct role in treatment due to its small size. The lack of an extensive root zone provide very little substrate for attached microbial growth. The growing plants form a single layer completely covering the water surface, then some species will grow on top of others leading to the formation of a thick mat. The formation of this mat is probably the most significant contribution of the duckweed plant to wastewater treatment. The surface cover prevents algae growth, stabilizes pH, and enhances sedimentation but is also likely to result in anaerobic conditions due to the relatively low photosynthetic oxygen production from the small plants.

The use of submerged aquatic macrophytes for treatment of wastewater has been tested in the laboratory and greenhouse and in a pilot scale field study in Michigan. The units with *Elodea nuttalli* did demonstrate significant removal of BOD, phosphorus, and nitrogen. The performance of these units was slightly better than the control units that contained no plants. The other plant species that were tested (*Myriophyllum heterophyllum, Ceratophyllum demersum)* were rapidly fouled with filamentous algae which in turn reduced productivity and system performance.

Natural Systems for Waste Management & Treatment by Sherwood C. Reed, E. Joe Middlerbrooks and Ronald W. Crites (McGraw Hill, New York, 1988)

contain information on the use of aquatic plants in wastewater treatment which is reproduced in part in Annex C.

Duckweed systems have been used in Bangladesh, for treatment of wastewater while generating employment and cash income through production of valuable protein-rich biomass usable locally as fish feed. Both a centralized treatment facility for a community of 25,000 and a number of pond-based village systems have been implemented in Bangladesh by the NGO PRISM. The PRISM program is documented in a World Bank publication (Skillicorn et al., 1993).

For the 1.6 million total projected 2015 population of the eight major urban centres of the Northeast Region, engineered wetlands on a total area of 160 to 320 ha would be required (0.1 to 0.2 ha per 1000 persons). These systems would produce duckweed at a rate of 160 to 320 T/day (yields are 1 T/ha-day), which in turn could be used to support daily aquaculture fish production of 16 to 32 T per day (duckweed to fish conversion of 0.1; duckweed is 45% protein by dry weight; Skillicorn et al., p. 53). A single system serving 100,000 people could have an area of 10 ha; produce 10 tonnes of duck weed per day; provide duckweed sufficient for aquaculture production of 1 tonne of fish per day, worth a gross value of Tk 50,000 per day (at Tk 50/kg), which is Tk 15 million (US$ 0.4 million) per year.

The potential environmental and economic value of aquatic wastewater systems seems clear. Treatment systems, whether conventional or aquatic, are however only one element in the management of material flows through the urban landscape (Appasamy and Lundqvist, 1993; Niemczynowicz, 1993; and Briscoe and Steer, 1993). As the feasibility of aquatic plant systems are investigated, there will also be a need to look specifically at wastewater collection (sewer system) options, with special attention to existing and expanding slum areas (Table 6.6) and more broadly at options to manage 'domestic' wastewater flow rates and contaminants through measures taken in the household and non-formal, informal, and small industrial sectors.

Content

A first step towards achieving acceptable treatment of regional urban domestic wastes would be to undertake feasibility studies for the largest urban areas of the Northeast (Sylhet, Narsingdi, Bhairab, Kishorganj, Sherpur, Netrokona, Habiganj, and Moulvibazar; NERP Study on Urbanization, 1993), and for representative *thana*/smaller centres and villages. Feasibility studies would need to emphasize local consultation with regard to institutional arrangements (for example, public-private joint venture), siting, and local resource mobilization. It is likely that a considerable part of the cost of these systems will come from the need to install or upgrade drains; experience in other countries suggests that neighbourhood resource mobilization and participation will be key (Briscoe and Steer, 1993).

In-depth investigations of the prospects of using water hyacinth should be an integral part of the feasibility study.

Given that rates of return on investment in this type of wastewater treatment can be quite attractive, private sector involvement in the construction and operation of treatment lagoons should be facilitated through training, credit, and access to suitable sites on public land.

Outputs Feasibility studies for the eight major urban centres and a selection of smaller towns. Credit facility for construction of treatment facilities by private entities.

Inputs Local and expatriate project staff. Credit funds.

Linkages To other NERP initiatives: linkage to the Pond Aquaculture project should be developed.

Table 6.6: Urban drainage and community participation
(reproduced from Briscoe and Steer, 1993)

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COMPONENT: **INSTITUTIONAL DEVELOPMENT**

The Institutional Development component is composed of three elements:

- Biodiversity strategic planning exercise
- Surface water quality management strategic planning exercise
- Creation of a Northeast Region Environment Management, Research, and Education Centre

Scope National

Objectives General: Develop national institutional framework, capabilities, and information resources in the area of biodiversity conservation, within the context of a strategic planning exercise.

Specific (partial list — planning exercise would revise and add):

- Support achievement of sustainability of the biophysical actions taken under NEMREP, through development of necessary national institutional elements (laws, expertise, etc.)
- Develop national wetland policies, expertise, and appropriate institutional structures such as inter-ministerial committee, expert panel, etc
- Develop information resources, such as a national wetland inventory; appropriate arrangements for access to geographic information system (GIS) capability would be helpful
- Support institutional strengthening in the area of social forestry
- Support GOB efforts to declare some or all of the nine key sites as Ramsar Convention sites, and to meet Ramsar Convention obligations
- Support GOB efforts to declare some or all of the nine key sites as national protected areas
- Support GOB efforts to meet Biodiversity Convention obligations, and to benefit from Convention provisions for assistance to developing countries in biodiversity conservation

Background The recent strengthening of national policies regarding biodiversity awaits commensurate national institutional development. In addition, overarching national policies regarding public participation, self-reliance, and so on, need to be incorporated in all national institutions, including those in these two areas.

Strategic planning at the highest level is needed to identify and develop programmes for the necessary key changes in legislation, agency mandate and regulations, staffing and staff training, interagency cooperation mechanisms, arrangements for public participation, and so on. In preparation for such an exercise, there is a need for staff development activities to heighten awareness of biodiversity issues, and of the value of biodiversity components.

An initial effort in this area was made by CIDA/IUCN in sponsoring a conference entitled "Conservation and Sustainable Management of Freshwater Wetlands" in December 1992 (IUCN, 1993b).

Content The role of the project would be to undertake a strategic planning exercise (taking the NERP strategic planning process as a starting point) for institutional development in the area of biodiversity. Dialogue with and among the interested

parties — those within and outside government, and from the grassroots, intermediate, and national levels — would be a key element. In parallel with this, the project would support immediate achievement of selected short-gestation strategic objectives (see list above), through technical assistance, training, support for national conferences and workshops, in-country field workshops, study tours to other Ramsar Convention and Biodiversity signatory countries, and similar inputs, with emphasis on participatory input from local and regional levels.

Outputs Strategic Plan for Institutional Development and Action to Conserve Biodiversity. Working papers on institutional and technical topics, conference and workshop proceedings, field workshop and study tour reports, and so on. Institutional upgrading in selected areas.

Inputs Local and expatriate project staff. Funding for training activities (conferences, workshops, study tours, etc.)

Assumptions Continued national policy and Department of Environment commitment to biodiversity conservation; wetlands; social forestry; and regulation of trade in threatened species.

COMPONENT: **INSTITUTIONAL STRENGTHENING AND DEVELOPMENT**
ELEMENT: **Surface Water Quality Management Strategic Planning Exercise**

Scope National

Objectives General: Improve the institutional framework for water quality improvement and management. Specific: Prepare and begin implementation of a strategic plan and action programme for water quality improvement and management, reflecting input from all interested parties

Background All aspects of water quality management — industrial pollution control, sewage treatment, access to safe domestic water and fixed latrines, water quality characterization and monitoring, public health education related to water — need to be strengthened. This is complicated by the fact that responsibility for water quality management is divided among a large number of entities.

A strategic planning exercise would allow a cross-cutting examination of water quality management issues, and would provide a venue for discussion among the various interested parties. The aim would be to develop and begin implementation of a strategy and programme to reduce pollution from industrial and domestic waste by deploying resources more efficiently, increasing the amount and effectiveness of private sector and people's participation, and by improving the coordination and integration of functions between entities.

The institutions involved in water quality management include the following. The Environment Pollution Control Directorate of the Department of Environment is responsible for water quality monitoring. The Municipal Corporations in each major urban centre are responsible for urban infrastructure, which includes urban water supply and sewage conveyance and treatment systems, development zoning, and so on. The Department of Public Health Engineering is responsible for rural water supply and sanitation. The Bangladesh Chemical Industries Corporation, under the Ministry of Industries, is by far the largest public sector industry, with 22 enterprises, including the four pulp and paper mills, and employing over 30,000 people to produce a wide range of products. There are a number of laboratories, within and outside of Government, which perform water quality analyses of various types. The Bangladesh Chemical Society, the professional society of chemists and chemical engineers, has taken a strong interest in pollution abatement technology. In addition, nationally there are 2000 private industrial concerns classified as pollution sources — the owners and managers of which would be the ones to implement actual pollution abatement measures.

Content The role of the project would be to undertake a strategic planning exercise (taking the NERP strategic planning process as a starting point) for institutional development in the area of surface water quality management. Dialogue with and

among the interested parties — those within and outside government, and from the grassroots, intermediate, and national levels — would be a key element.

Given the number of major institutional players, a key question will be means to achieve an appropriate level of cooperation and information exchange among them. It is unrealistic to suppose, for example, that centralizing water quality characterization will achieve anything in the way of better water quality management: what is needed is not the better data base itself, but heightened awareness and better analysis of water quality, and greater use of water quality data to plan and evaluate management measures.

One possibility would be a national committee on water quality, perhaps affiliated with the Bangladesh Chemical Society, which claims as members many major players in water quality management — academics, private consultants, government bureaucrats, BCIC managers, chemists and chemical engineers in private industry, and so on. The Committee could meet annually immediately before or after the regular, well-attended BCS meeting. An important requirement would be for mandatory exchange of water quality data at each meeting. Measures would obviously have to be taken to gain the participation of interested parties from other disciplines than chemistry, and from/representing strata other than the professional elite; the point being made is that an organization such as BCS is well-positioned to take a leading role.

Outputs Strategic Plan for Institutional Development to Improve Surface Water Quality Management. Working papers on institutional and technical topics, conference and workshop proceeding, field workshop and study tour reports, and so on.

Inputs Local and expatriate project staff. Funding for training activities.

COMPONENT: **INSTITUTIONAL STRENGTHENING AND DEVELOPMENT**
ELEMENT: **Creation of a Northeast Region Environmental Management, Research, and Education Centre (NEMREC)**

Scope Regional

Objectives Support the creation of a regional institution capable of addressing biodiversity, surface water quality, and related concerns; which is sustainable, transparent, and efficient, responsive to changing opportunities and threats, and has proper accountability.

This institution, once operational, would have among its objectives to sustain and elaborate initiatives begun under NEMREP. This could involve environmental monitoring; backstopping local resource managers; undertaking and supporting needed biophysical and social research; facilitating information exchange; supporting local projects and research; raising awareness at all levels through a wide variety of means; and supporting human resource development through scholarships and the like. In addition, the institution could contribute to EIAs of development projects in the region, and so on.

Background Improved surface water quality management and biodiversity conservation will not be achieved by unilateral central government action, nor by direct partnership between local people and central government bureaucrats. There is a need for institutional development at intermediate levels. A regional-level institution is ideally suited to fill this gap, with the scale and competence to command national attention, while keeping a primary orientation towards the needs and views of residents and communities in the region. Such a regional institution would also provide assistance in mobilizing local and regional input to environmental planning, assessment, and management of development projects.

The functions and needed qualities of this institution suggest that it should be private rather than governmental, and specifically should follow the NGO model, which is widely understood and successful in Bangladesh, and recognized and governed by specific national legislation. The first step in creating a new NGO is to establish a Convening Committee. This group prepares a draft organizational plan following a standard format established by the Ministry of Social Welfare. This document includes a draft constitution identifying goals, objectives, and areas of activity. Then the Committee would organize and convene meetings of a General Membership.

In the case of NEMREC, the General Membership would be open to all interested parties or their representatives. The General Membership then elects a Executive Committee of eleven or more members. The Executive Committee finalizes the constitution (which must define *inter alia* regular meeting and election intervals, membership categories and criteria) and registers with the Government. The Executive Committee is responsible to meet legal requirements for proper accounting and other types of records.

In the design of NEMREC's organizational structure, some thought should be given to whether it should be organized as a meta-NGO (an organization which has as a main objective to coordinate inputs etc. of a number of other NGOs and other interested parties; existing examples would include ADAB), or whether a straight NGO organization is preferable. On the one hand, a meta-NGO, perhaps organized around a secretariat, would emphasize consultation and cooperation; on the other hand, there are clear organizational and political risks (i.e. bureaucratic or political paralysis) to the ability to achieve real-world objectives associated with formalizing this within the organizational structure.

Content

- Prepare an organizational structure and action plan for the Centre, including plans for set up and for handover of ongoing tasks emanating from NEMREP, reflecting input from public consultations involving all interested parties. Plan would include a strategy for establishing an adequate, stable future funding base
- Support the process of setting up the Centre directorate, operational staff, and physical facilities
- Work in partnership with the Centre to transfer ongoing tasks emanating from NEMREP, and to establish other activities included in operational plan

Outputs

NEMREC Organizational Structure and Action Plan. Sustainable NEMREC engaged in ongoing tasks emanating from NEMREP, plus any other activities defined in operational plan.

Inputs

Local and expatriate project staff. Funds for NEMREC facilities, laboratory equipment, library, and so on. Bridging funding until other sources of funds can be mobilized.

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ANNEX A

FIGURES

Figure 1

LEGEND

- International Boundary
- NERP Boundary
- River/Khal
- Uplands
- Haor and Flood Basin

BANGLADESH

0 150km

Jamuna R
Ganges R
DHAKA
Meghna R
BAY OF BENGAL

Meghalaya Foothills

Durgapur
Someswari R
Nitai R
Ichhamati R
Chhiltakhali R
Bhogai R
Sherpur
Mrigi R
Old Brahmaputra R
Kangsa R
Netrokona
Mogra R
Mymensingh
Saduki R
Jadukata R
Dhalai R
Chiwa R
Dhalaigang
Piyain R
Kurt R
Lubha R
Sunamganj
Companiganj
Chhatak
Sari-Gowain R
Kanairghat
Surma R
Sylhet
Sheola
Amaishide
Barak R
Dorasi R
Kalni R
Markuli
Ajmiriganj
Fenchuganj
Senai
Sherpur
Kushiyara R
Moulvibazar
Juri
Manu R
Kishoreganj
Habiganj
Sutang R
Khowai R
Dhalai R
Barasi R
Arial Khan R
Meghna R
Bhairab Bazar
Lahirya R
Tripura Hills

92°30'
25°15'
90°30'
24°00'

N

25km 0 25 50km

Scale

The Northeast Region

Figure 2

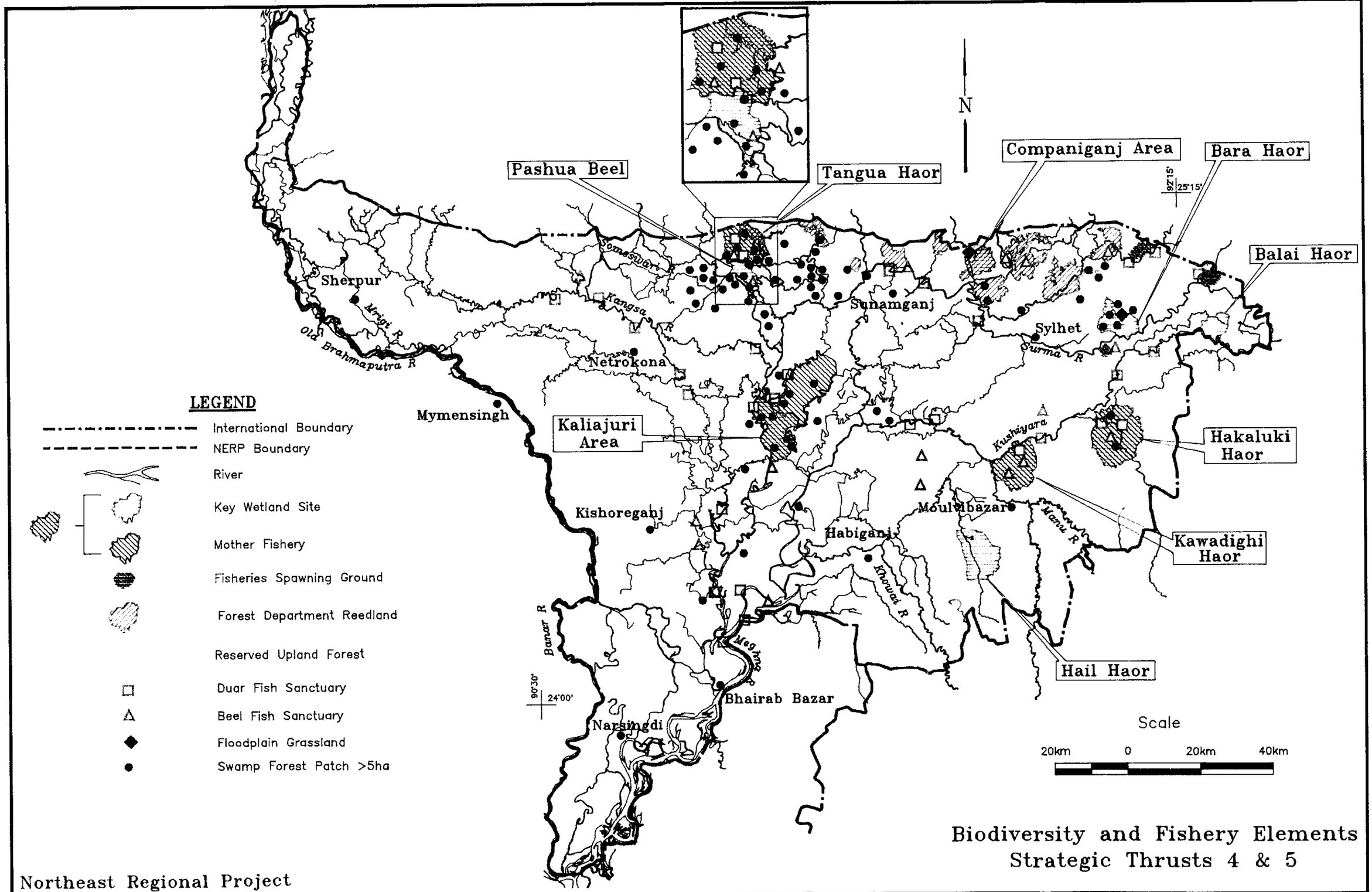

N
Pashua Beel
Tangua Haor
Companiganj Area
Bara Haor
Balai Haor
Hakaluki Haor
Kawadighi Haor
Hail Haor
Kaliajuri Area
Sherpur
Mymensingh
Netrokona
Kishoreganj
Sunamganj
Sylhet
Moulvibazar
Habiganj
Bhairab Bazar
Narsingdi
Someshwari
Kangsa R
Mrigi R
Old Brahmaputra R
Surma R
Kushiyara
Manu R
Khowai R
Baner R
Meghna
90°30'
24°00'
92°15'
25°15'
LEGEND
International Boundary
NERP Boundary
River
Key Wetland Site
Mother Fishery
Fisheries Spawning Ground
Forest Department Reedland
Reserved Upland Forest
Duar Fish Sanctuary
Beel Fish Sanctuary
Floodplain Grassland
Swamp Forest Patch >5ha
Scale
20km 0 20km 40km
Biodiversity and Fishery Elements
Strategic Thrusts 4 & 5
Northeast Regional Project

Figure 3: Work breakdown structure

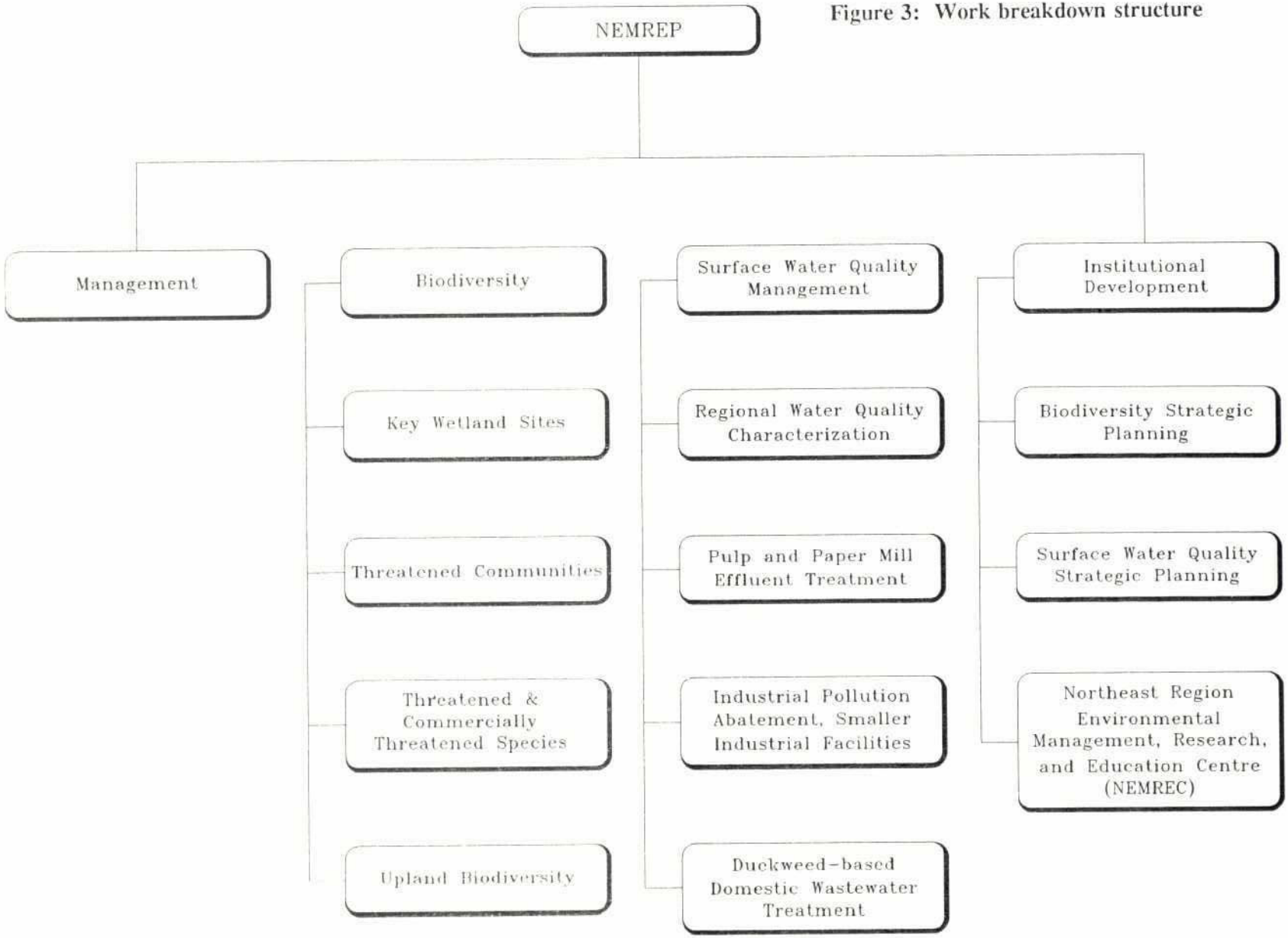


Figure 4: Work breakdown structure, detail

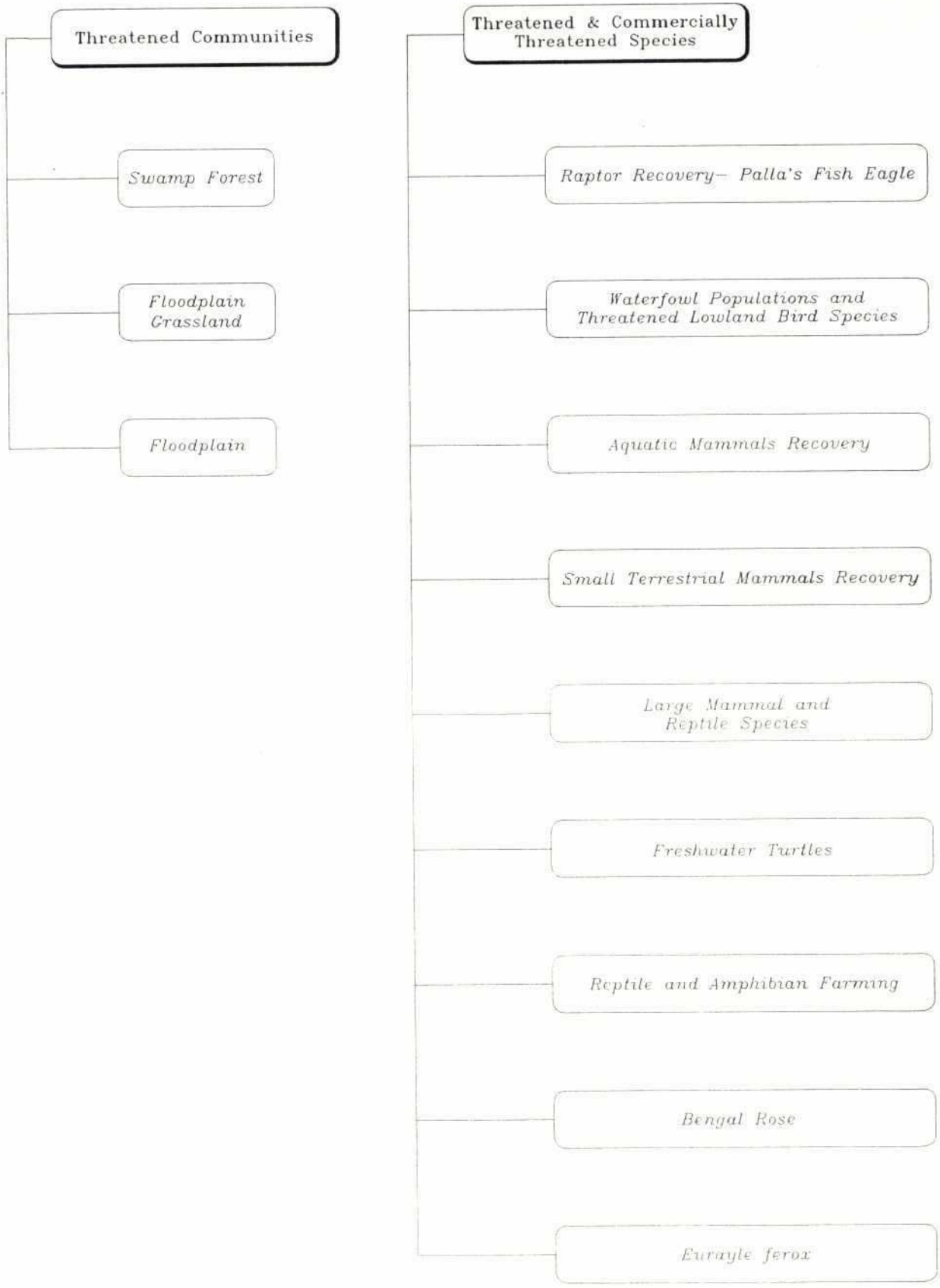


Figure 5: Phasing

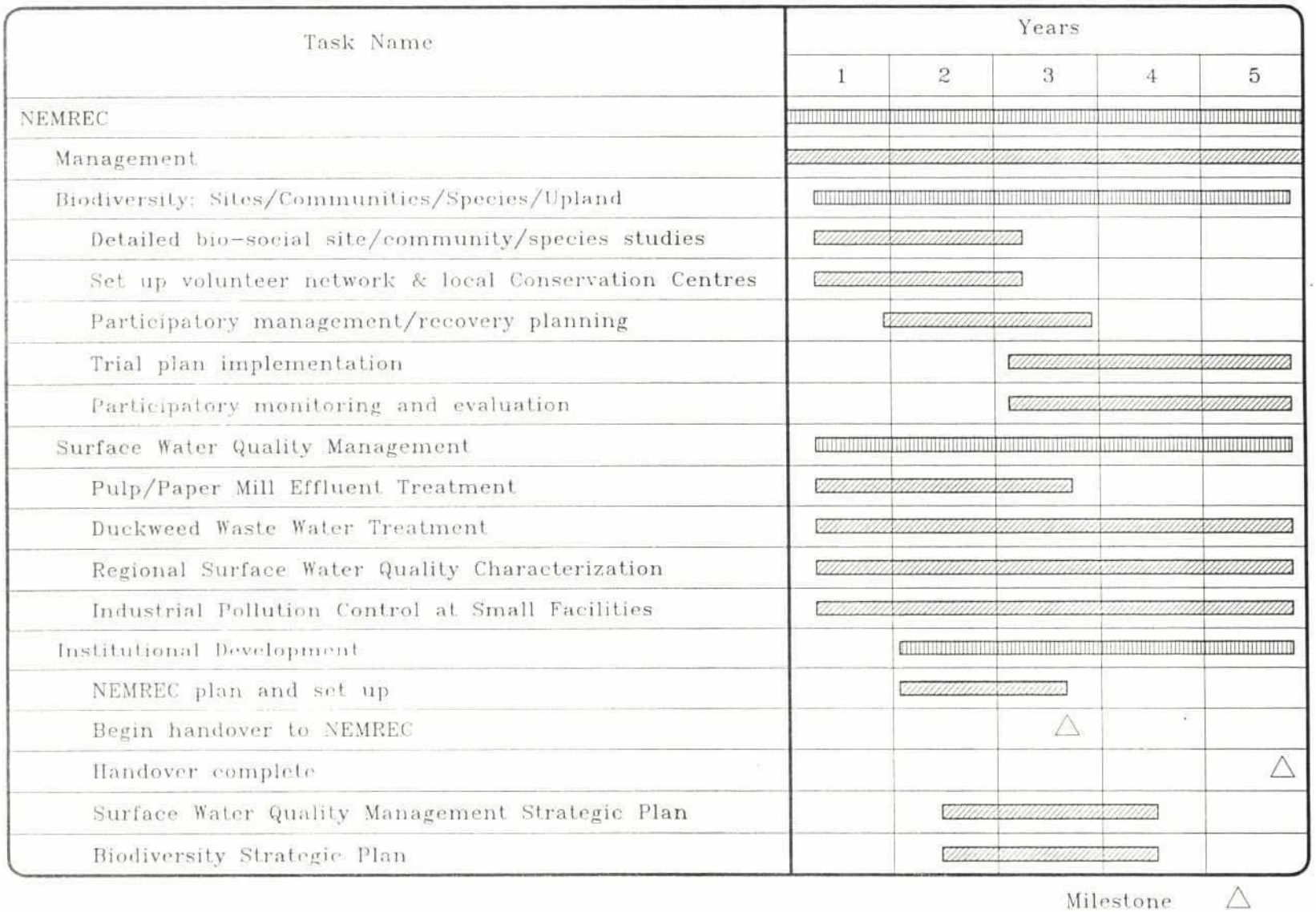
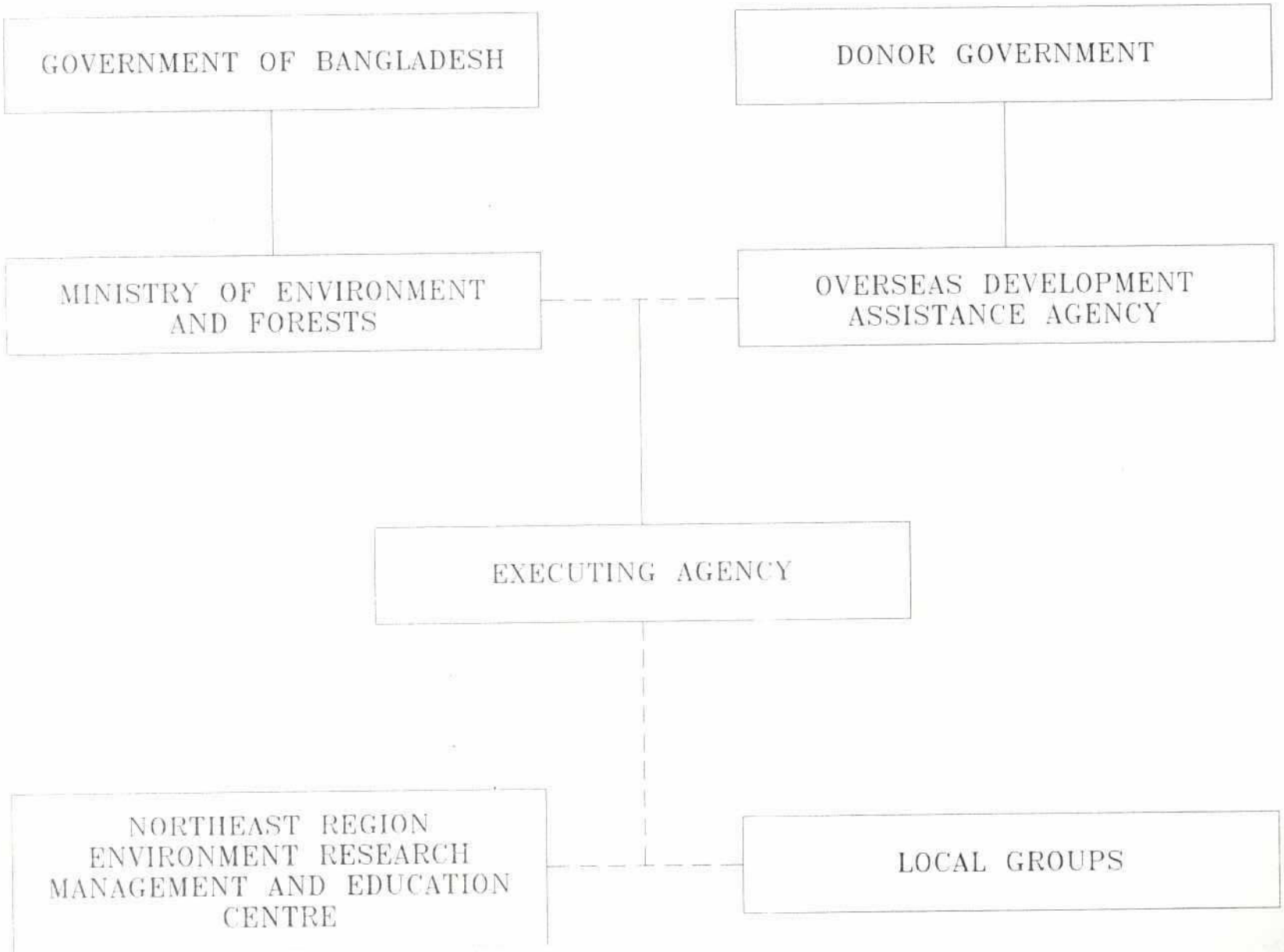


Figure 6: **NEMREP organizational structure**



ANNEX B

SPECIES LISTS

Table B.1: Bird species of the Northeast Region

Notes: The nomenclature and sequence follows King and Dickinson (1975). The 370 species listed here are all those observed during NERP 1992-3 field work, plus 36 waterfowl species known or thought to inhabit the region now or previously. + indicates upland forest birds, * indicates waterfowl; unmarked species can be found in both habitats.

* ***Great Crested Grebe*** *Podiceps cristatus*
* ***Little Grebe*** *Tachybaptus ruficollis*
* ***Great Cormorant*** *Phalacrocorax carbo*
* ***Little Cormorant*** *Phalacrocorax niger*
* ***Oriental Darter*** *Anhinga melanogaster*
* ***Grey Heron*** *Ardea cinerea*
* ***Purple Heron*** *Ardea purpurea*
* ***Large Egret*** *Ardea alba*
* ***Pond Heron*** *Ardeola grayii*
* ***Chinese Pond Heron*** *Ardeola bacchus*
Little Heron *Butorides straitus*
Cattle Egret *Bubulcus ibis*
* ***Intermediate Egret*** *Egretta intermedia*
* ***Little Egret*** *Egretta garzetta*
Night Heron *Nycticorax nycticorax*
\+ ***Tiger Bittern*** *Gorsachius melanocephalus*
\+ ***Little Bittern*** *Ixobrychus minutus*
Cinnamon Bittern *Ixobrychus cinnamomeus*
* ***Yellow Bittern*** *Ixobrychus sinensis*
\+ ***Black Bittern*** *Dupetor flavicollis*
Great Bittern *Botaurus stellaris*
Asian Openbill *Anastomus oscitans*
Lesser Adjutant Stork *Leptoptilos javanicus*
* ***Black-headed Ibis*** *Threskiornis aethiopica*
* ***White Spoonbill*** *Platalea leucorodia*
* ***Bar-headed Goose*** *Anser indicus*
* ***Lesser Whistling Duck*** *Dendrocygna javanica*
* ***Fulvous Whistling Duck*** *Dendrocygna bicolor*
* ***Ruddy Shelduck*** *Tadorna ferruginea*
* ***Common Shelduck*** *Tadorna tadorna*
* ***Pintail*** *Anas acuta*
* ***Common Teal*** *Anas crecca*
* ***Spotbill Duck*** *Anas poecilorhynchus*
* ***Mallard*** *Anas platyrhynchos*
* ***Gadwall*** *Anas strepera*
* ***Falcated Teal*** *Anas falcata*
* ***Eurasian Wigeon*** *Anas penelope*
* ***Garganey*** *Anas querquedula*
* ***Shoveller*** *Anas clypeata*
* ***Red-crested Pochard*** *Netta rufina*
* ***Ferrugunous Duck*** *Aythya nyroca*
* ***Baer's Pochard*** *Aythya baeri*
* ***Tufted Duck*** *Aythya fuligula*
* ***Greater Scaup*** *Aythya marila*
* ***Cotton Pygmy Goose*** *Nettapus coromendelianus*
* ***Comb Duck*** *Sarkidiornis melanotos*
Black-winged Kite *Elanus caeruleus*
\+ ***Black-crested Baza*** *Aviceda leuphotes*
\+ ***Honey Buzzard*** *Pernis ptilorhynchos*
Black Kite *Milvus migrans*
Brahminy Kite *Haliastur indus*
\+ ***Goshawk*** *Accipiter gentilis*
\+ ***Shikra*** *Accipiter badius*
\+ ***Crested Goshawk*** *Accipiter trivirgatus*
\+ ***White-eyed Buzzard Eagle*** *Butastur teesa*
\+ ***Changable Hawk-Eagle*** *Spizaetus cirrhatus*
Tawny Eagle *Aquila rapax*
\+ ***Greater Spotted Eagle*** *Aquila clanga*
\+ ***Lesser Spotted Eagle*** *Aquila pomarina*
\+ ***Steppe Eagle*** *Aquila nipalensis*
\+ ***Malayan Eagle*** *Ictinaetus malayensis*
* ***Pallas's Fish Eagle*** *Haliaeetus leucoryphus*
* ***Grey-headed Fish Eagle*** *Icthyophaga ichthyaetus*
Griffon Vulture *Gyps fulvus*
Long-billed Vulture *Gyps indicus*
White-rumped Vulture *Gyps bengalensis*
Hen Harrier *Circus cyaneus*
Pied Harrier *Circus melanoleucos*
* ***Western Marsh Harrier*** *Circus aeroginosus*
* ***Eastern Marsh Harrier*** *Circus spilonotus*
\+ ***Crested Serpent Eagle*** *Spilornis cheela*
* ***Osprey*** *Pandion haliaetus*
Peregrine Falcon *Falco peregrinus*
\+ ***Northern Hobby*** *Falco subbuteo*
\+ ***Oriental Hobby*** *Falco severus*
\+ ***Red-headed Merlin*** *Falco chiquera*
Eurasian Kestrel *Falco tinnunculus*
* ***Swamp Partridge*** *Francolinus gularis*
Rain Quail *Coturnix coromendelica*
Blue-breasted Quail *Coturnix chinensis*
\+ ***Manipur Bush Quail*** *Perdicula manipuriensis*
\+ ***Rufous-throated Hill Partridge*** *Arborophila rufogularis*
\+ ***Kalij Pheasant*** *Lophura leucomelana*
\+ ***Red Jungle Fowl*** *Gallus gallus*
\+ ***Peacock Pheasant*** *Polyplectron bicalcaratum*
\+ ***Bustard Quail*** *Turnix suscitator*

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+ ***Slaty-breasted Rail*** *Gallirallus straitus*
+ ***Water Rail*** *Rallus aquaticus*
+ ***Ruddy Crake*** *Porzana fusca*
White-breasted Waterhen *Amaurornis phoenicurus*
* ***Watercock*** *Gallicrex cinerea*
* ***Purple Swamphen*** *Porphyrio porphyrio*
* ***Common Moorhen*** *Gallinula chloropus*
* ***Coot*** *Fulica atra*
* ***Pheasant-tail Jacana*** *Hydrophasianus chirurgus*
* ***Bronze-winged Jacana*** *Metopidius indicus*
* ***Painted Snipe*** *Rostratula benghalensis*
* ***Black-winged Stilt*** *Himantopus himantopus*
* ***Pied Avocet*** *Recurvirostra avosetta*
* ***Oriental Pratincole*** *Glareola maldivarum*
* ***Small Pratincole*** *Glareola lactea*
* ***Grey-headed Lapwing*** *Vanellus cinereus*
Red-wattled Lapwing *Vanellus indicus*
* ***River Lapwing*** *Vanellus spinosus*
Yellow-wattled Lapwing *Vanellus malabaricus*
* ***Pacific Golden Plover*** *Pluvialis fulva*
* ***Grey Plover*** *Pluvialis squatarola*
* ***Large Sand Plover*** *Charadrius leschenaultii*
* ***Little Ringed Plover*** *Charadrius dubius*
* ***Kentish Plover*** *Charadrius alexandrinus*
* ***Longbilled Plover*** *Charadrius placidus*
* ***Mongolian Plover*** *Charadrius mongolus*
* ***Whimbrel*** *Numenius phaeopus*
* ***Curlew*** *Numenius arquata*
* ***Blacktailed Godwit*** *Limosa limosa*
* ***Bartailed Godwit*** *Limosa japonica*
* ***Spotted Redshank*** *Tringa erythropus*
* ***Common Redshank*** *Tringa totanus*
* ***Marsh Sandpiper*** *Tringa stagnatilis*
* ***Greenshank*** *Tringa nebularia*
* ***Wood Sandpiper*** *Tringa glareola*
* ***Spotted Greenshank*** *Tringa guttifer*
* ***Terek Sandpiper*** *Tringa terek*
* ***Common Sandpiper*** *Actitis hypoleucos*
Pintail Snipe *Gallinago stenura*
Fantail Snipe *Gallinago gallinago*
* ***Swinhoe's Spine*** *Gallinago megala*
* ***Sanderling*** *Calidris alba*
* ***Little Stint*** *Calidris minuta*
* ***Temminck's Stint*** *Calidris temminckii*
* ***Longtoed Stint*** *Calidris subminuta*
* ***Dunlin*** *Calidris alpina*
* ***Curlew Sandpiper*** *Calidris testacea*
* ***Broadbilled Sandpiper*** *Limicola falcinellus*
* ***Ruff & Reeve*** *Philomachus pygnax*
* ***Herring Gull*** *Larus argentatus*
* ***Great Blackheaded Gull*** *Larus ichthyaetus*
* ***Brownheaded Gull*** *Larus brunnicephalus*
* ***Blackheaded Gull*** *Larus rudibundus*
* ***Whiskered Tern*** *Chlidonias hybrida*
* ***White-winged Tern*** *Childonias leucopterus*
* ***Gull-billed Tern*** *Gelochelidon nilotica*
* ***Caspian Tern*** *Hydroprogne caspia*
* ***Indian River Tern*** *Sterna aurantia*
* ***Common Tern*** *Sterna hirundo*
* ***Little Tern*** *Sterna albifrons*
+ ***Pin-tailed Pigeon*** *Treron apicauda*
+ ***Wedge-tailed Pigeon*** *Treron sphenura*
+ ***Yellow-footed Pigeon*** *Treron phoenicoptera*
+ ***Grey-fronted Pigeon*** *Treron pompadora*
+ ***Orange-breasted Pigeon*** *Treron bicincta*
+ ***Green Pigeon*** *Ducula aenea*
+ ***Imperial Pigeon*** *Ducula badia*
Blue Rock Pigeon *Columba livia*
+ ***Rufous Turtle Dove*** *Streptopelia orientalis*
+ ***Ring Dove*** *Streptopelia decaocto*
+ ***Red Turtle Dove*** *Streptopelia tranquebarica*
+ ***Spotted Dove*** *Streptopelia chinensis*
+ ***Emerald Dove*** *Chalcophaps indica*
+ ***Large Indian Parakeet*** *Psittacula eupatria*
+ ***Rose-ringed Parakeet*** *Psittacula krameri*
+ ***Red-breasted Parakeet*** *Psittacula alexandari*
+ ***Vernal Hanging Parrot*** *Loriculus vernalis*
+ ***Pied Crested Cuckoo*** *Clamator jacobinus*
+ ***Common Hawk Cockoo*** *Cuculus varius*
+ ***Indian Cuckoo*** *Cuculus micropterus*
+ ***Himalayan Cuckoo*** *Cuculus saturatus*
+ ***Common Cuckoo*** *Cuculus canorus*
+ ***Grey-bellied Cuckoo*** *Cacomantis passerinus*
+ ***Plaintive Cuckoo*** *Cacomantis merulinus*
+ ***Emarald Cuckoo*** *Chalcites maculatus*
+ ***Drongo Cuckoo*** *Surniculus lugubris*
+ ***Common Koel*** *Eudynamus scolopacea*
+ ***Large Green-billed Malkoha*** *Rhopodytes tristis*
+ ***Sirkeer Cuckoo*** *Taccocua leschenaultii*
+ ***Greater Coucal*** *Centropus sinensis*
+ ***Lesser Coucal*** *Centropus bengalensis*
Barn Owl *Tyto alba*
+ ***Spotted Scops Owl*** *Otus spilocephalus*
+ ***Scops Owl*** *Otus scops*
+ ***Collared Scops Owl*** *Otus bakkamoena*
+ ***Eagle Owl*** *Bubo bubo*
+ ***Forest Eagle Owl*** *Bubo nipalensis*
+ ***Dusky Horned Owl*** *Bubo coromandus*
+ ***Brown Fish Owl*** *Ketupa zeylonensis*
+ ***Tawny Fish owl*** *Bubo flavipes*
+ ***Barred Owlet*** *Glaucidium cuculoides*
+ ***Brown Hawk Owl*** *Ninox scutulata*
+ ***Spotted Owlet*** *Athene brama*
+ ***Jungle Nightjar*** *Caprimulgus indicus*

+ ***Longtailed Nightjar*** *Caprimulgus macrurus*
+ ***Franklin's Nightjar*** *Caprimulgus affinis*
+ ***Alpine Swift*** *Apus melba*
House Swift *Apus affinis*
Palm Swift *Cypsiurus balasiensis*
+ ***Red-headed Trogon*** *Harpactes erythrocephalus*
* ***Pied Kingfisher*** *Ceryle rudis*
+ ***Black-backed Kingfisher*** *Ceyx erithacus*
* ***Common Kingfisher*** *Alcedo atthis*
+ ***Stork-billed Kingfisher*** *Pelargopsis capensis*
* ***White-throated Kingfisher*** *Halcyon smyrnensis*
+ ***Chestnut-headed Bee-eater*** *Merops leschenaulti*
+ ***Blue-tailed Bee-eater*** *Merops philipinus*
Green Bee-eater *Merops orientalis*
+ ***Blue-bearded Bee-eater*** *Nyctyornis athertoni*
+ ***Indian Roller*** *Coracias benghalensis*
+ ***Broad-billed Roller*** *Eurystomus orientalis*
+ ***Hoopoe*** *Upupa epops*
+ ***Indian Pied Hornbill*** *Anthracoceros malabaricus*
+ ***Lineated Barbet*** *Megalaima lineata*
+ ***Blue-throated Barbet*** *Megalaima asiatica*
+ ***Blue-eared Barbet*** *Megalaima australis*
+ ***Coppersmith Barbet*** *Magalaima haemacephala*
+ ***Wryneck*** *Junx torquilla*
+ ***Speckeled Piculet*** *Picumnus innominatus*
+ ***Rufous Piculet*** *Sasia ochracea*
+ ***Rufous Woodpecker*** *Micropternus brachyurus*
+ ***Little Green Woodpecker*** *Picus myrmecophoneus*
+ ***Grey-headed Woodpecker*** *Picus canus*
+ ***Greater Yellownape*** *Picus flavinucha*
+ ***Black-rumped Flameback*** *Dinopium bengalense*
+ ***Fulvous-breasted Woodpecker*** *Picoides macei*
+ ***Yellow-fronted Woodpecker*** *Picoides mahrattensis*
+ ***Hodgson's Broadbill*** *Serilophus lunatus*
+ ***Indian Pitta*** *Pitta brachyura*
+ ***Hooded Pitta*** *Pitta sordida*
Bush Lark *Mirafra assamica*
Red-winged Bush Lark *Mirafra erythroptera*
Short-toed Lark *Calandrella sp.*
Oriental Skylark *Alauda gulgula*
+ ***Finch Lark*** *Eremopterix grisea*
* ***Plain Martin*** *Riparia paludicola*
* ***Collared Sand Martin*** *Riparia riparia*
Barn Swallow *Hirundo rustica*
Red-rumped Swallow *Hirundo daurica*
+ ***Grey Shrike*** *Lanius excubator*
+ ***Black-headed Shrike*** *Lanius schach*
+ ***Brown Shrike*** *Lanius cristatus*
+ ***Black-naped Oriole*** *Oriolus chinensis*
+ ***Black-headed Oriole*** *Oriolus xanthornus*
Black Drongo *Dicrurus adsimilis*
+ ***Ashy Drongo*** *Dicrurus leucophaeus*
+ ***Crow-billed Drongo*** *Dicrurus annectans*
+ ***Bronzed Drongo*** *Dicrurus aeneus*
+ ***Lesser Racket-tail Drongo*** *Dicrurus remifer*
+ ***Greater Racket-tail Drongo*** *Dicrurus paradiseus*
Swallow Shrike *Artamus fuscus*
+ ***Glossy Stare*** *Aplonis panayensis*
Grey-headed Myna *Sturnus malabaricus*
Pied Myna *Sturnus contra*
Common Myna *Acridotheres tristis*
Jungle Myna *Acridotheres fuscus*
+ ***Hill Myna*** *Gracula religiosa*
+ ***Green Magpie*** *Cissa chinensis*
+ ***Blue Magpie*** *Cissa flavirostris*
+ ***Treepie*** *Dendrocitta vagabunda*
+ ***Himalayan Treepie*** *Dendrocitta formosae*
House Crow *Corvus splendens*
Jungle Crow *Corvus macrorhynchus*
+ ***Flycatcher-Shrike*** *Hemipus picatus*
+ ***Common Wood Shrike*** *Tephrodornis pondicerianus*
+ ***Large Wood Shrike*** *Tephrodornis virgatus*
+ ***Black-faced Cuckoo-Shrike*** *Coracina novaehollandiae*
+ ***Black-winged Cuckoo-Shrike*** *Coracina melaschistos*
+ ***Scarlet Minivet*** *Pericrocotus flammeus*
+ ***Small Minivet*** *Pericrocotus cinnamommeus*
+ ***Common Iora*** *Aegithina tiphia*
+ ***Gold-fronted Leafbird*** *Chloropsis aurifrons*
+ ***Gold-mantled Leafbird*** *Chlorosis cochinchinensis*
+ ***Fairy Bird*** *Irena puella*
+ ***Black-headed Bulbul*** *Pycnonotus articeps*
+ ***Black-crested Bulbul*** *Pycnonotus melanicterus*
+ ***Red-whiskered Bulbul*** *Pycnonotus jocosus*
Red-vented Bulbul *Pycnonotus cafer*
+ ***White-throated Bulbul*** *Criniger flaveolus*
+ ***Olive Bulbul*** *Hypsipetes viridescens*
+ ***Ashy Bulbul*** *Hypsipetes flavala*
+ ***Black Bulbul*** *Hypsipetes madagascariensis*
+ ***Spotted Babbler*** *Pellorneum ruficeps*
+ ***Buff-breasted Babbler*** *Trichastoma tickelii*
+ ***Abbot's Babbler*** *Trichastoma abbotti*
+ ***Scimitar Babbler*** *Pomatorhinus hypoleucos*

+ ***Long-billed Wren Babbler*** *Rimator malacoptilos*
+ ***Lesser Wren Babbler*** *Pnoepyga pusilla*
+ ***Spotted Wren Babbler*** *Spelaeornis formosus*
+ ***Red-fronted Babbler*** *Stachyris rufifrons*
+ ***Yellow-eyed Babbler*** *Chrysomma sinense*
+ ***Common Babbler*** *Turtoides caudatus*
+ ***Straited Babbler*** *Turtoides earlei*
+ ***Jungle Babbler*** *Turtoides striatus*
+ ***Necklaced Laughing Thrush*** *Garrulax moniligerus*
+ ***Black-gorgeted Laughing Thrush*** *Garrulax pectoralis*
+ ***White-crested Laughing Thrush*** *Garrulax leucolophus*
+ ***Red-headed Laughing Thrush*** *Garrulax erythrocephalus*
+ ***Silver-eared Mesia*** *Leiothrix argentauris*
+ ***Shrike Babbler*** *Pteruthius melanotis*
+ ***Chestnut-headed Yuhina*** *Yuhina castaniceps*
+ ***Black-chinned Yuhina*** *Yuhina nigrimenta*
+ ***White-bellied Yuhina*** *Yuhina xantholeuca*
+ ***Quaker Babbler*** *Alcippe poioicephala*
+ ***Nepal Babbler*** *Alcippe nepalensis*
+ ***Long-tailed Sibia*** *Heterophasia picaoides*
+ ***Sooty Flycatcher*** *Muscicapa sibirica*
+ ***Brown Flycatcher*** *Muscicapa latirostris*
+ ***Red-breasted Flycatcher*** *Muscicapa parva*
+ ***Blue-throated Flycatcher*** *Muscicapa rubeculoides*
+ ***Tickell's Blue Flycatcher*** *Muscicapa tickelliae*
+ ***Verditer Flycatcher*** *Muscicapa thalassina*
+ ***Grey-headed Flycatcher*** *Culicicapa ceylonensis*
+ ***White-browed Fantail*** *Rhipidura aureola*
+ ***White-throated Fantail*** *Rhipidura albicollis*
+ ***Paradise Flycatcher*** *Terpsiphone paradisi*
+ ***Black-naped Flycatcher*** *Hypothymis azurea*
+ ***Spotted Bush Warbler*** *Bradypterus thoracicus*
+ ***Brown Bush Warbler*** *Bradypterus luteoventris*
+ ***Fantail Warbler*** *Cisticola exilis*
+ ***Ashy Wren Warbler*** *Prinia socialis*
+ ***Tailor Bird*** *Orthotomus sutorius*
+ ***Goldenheaded Tailor Bird*** *Orthotomus cuculatus*
+ ***Pallas's Warbler*** *Locustella certhiola*
+ ***Grasshopper Warbler*** *Locustella naevia*
+ ***Straited Marsh Warbler*** *Megaurus palustris*
+ ***Thickbilled Warbler*** *Acrocephalus aedon*
* ***Great Reed Warbler*** *Acrocephalus stentorius*
* ***Blyth's Reed Warbler*** *Acrocephalus dumetorum*
* ***Paddyfield Warbler*** *Acrocephalus agricola*
+ ***Chiffchaff*** *Phylloscopus collybita*
+ ***Tickell's Leaf Warbler*** *Phylloscopus affinis*
+ ***Dusky Leaf Warbler*** *Phylloscopus fuscatus*
+ ***Yelloweyed Flycatcher Warbler*** *Seicercus burkii*
+ ***Rubythroat*** *Erithacus callipoe*
+ ***Bluethroat*** *Erithacus svecicus*
+ ***Himalayan Rubythroat*** *Erithacus pectoralis*
+ ***Magpie Robin*** *Copsychus saularis*
+ ***Shayma*** *Chopsychus malabaricus*
+ ***Black Redstart*** *Phoenicurus ochruros*
+ ***Plumbeous Redstart*** *Rhyacornis fuliginosus*
+ ***Black-backed Forktail*** *Enicurus immaculatus*
+ ***Spotted Forktail*** *Enicurus maculatus*
+ ***Collared Bush Chat*** *Saxicola torquata*
+ ***Pied Bush Chat*** *Saxicola caprata*
+ ***Jerdon's Bush Chat*** *Saxicola jerdoni*
+ ***Blue Rock Thrush*** *Monticola solitarius*
+ ***Blue Whistling Thrush*** *Myiophonus caeruleus*
+ ***Orangeheaded Ground Thrush*** *Zoothera citrina*
+ ***Black-breasted Thrush*** *Turdus dissimilis*
+ ***Grey Tit*** *Parus major*
+ ***Velvet-fronted Nuthatch*** *Sitta frontalis*
+ ***Olive Tree Pipit*** *Anthus hodgsoni*
+ ***Paddyfield Pipit*** *Anthus novaeseelandiae*
+ ***Red-throated Pipit*** *Anthus cervinus*
+ ***Rosy Pipit*** *Anthus roseatus*
+ ***Forest Wagtail*** *Dendronanthus indicus*
* ***Yellow Wagtail*** *Motacilla flava*
* ***Yellow-headed Wagtail*** *Motacilla citreola*
* ***Grey Wagtail*** *Motacilla cinerea*
* ***White Wagtail*** *Motacilla alba*
Pied Wagtail *Motacilla maderaspatensis*
+ ***Thick-billed Flowerpecker*** *Dicaeum agile*
+ ***Tickell's Flowerpecker*** *Dicaeum erythrorhynchos*
+ ***Scarlet-backed Flowerpecker*** *Dicaeum cruentatum*
+ ***Rubycheek*** *Anthreptes singalensis*
+ ***Purple-rumped Sunbird*** *Nectarina zeylonica*
+ ***Van Hasselt's Sunbird*** *Nectarina sperata*
+ ***Purple Sunbird*** *Nectarina asiatica*
+ ***Mrs. Gould Sunbird*** *Aethopyga gouldie*
+ ***Yellow-backed Sunbird*** *Aethopyga siparaja*
+ ***Little Spiderhunter*** *Arachnothera longiristris*
+ ***Streaked Spiderhunter*** *Arachnothera magna*
+ ***White-eye*** *Zosterops palpebrosa*
House Sparrow *Passer domesticus*
Baya *Ploceus philippinus*

Black-throated Weaver Bird *Ploceus benghalensis*
Red Munia *estrilda amandava*
\+ ***Common Silverbill*** *Lonchura malabarica*
\+ ***Nutmeg*** *Lonchura atriata*
\+ ***Spotted Munia*** *Lonchura punctulata*
\+ ***Black-headed Munia*** *Lonchura malacca*
\+ ***Black-faced Bunting*** *Emberiza spodocephala*
\+ ***Chestnut-eared Bunting*** *Emberiza fucata*
\+ ***Yellow-breasted Bunting*** *Emberiza aureola*
\+ ***Crested Bunting*** *Melophus lathami*

Table B.2: Lowland mammal, reptile, and amphibian species

Name			IUCN						CITES			Wildlife Act		Current regional observations	
Scientific	English	Bangla	Ex	E	V	R	I	K	I	II	III	P	G	NERP	Other
CLASS MAMMALIA															
Order Primates															
Family Cercopithecidae															
Macaca mulatta	Rhesus Macaque	banor													R
Order Pholidota															
Family Manidae															
Manis crassicaudata	Indian Pangolin	bon rui								x		x		3	
Order Lagomorpha															
Family Leporidae															
Caprolagus hispidus	Hispid Hare	khorgosh		x					x			x		2	
Lepus nigricolles	Rufoustailed Hare	sashak										x		2	
Order Rodentia															
Family Sciuridae															
Cllosciurus pygerythrus	Irrawaddy Squirrel	badami kathbirali												1	
Family Hystricidae															
Hystrix indica	Indian Porcupine	sajaru												1	
Family Muridae															
Bandicota bengalensis	Mole Rat	indur												1	
Bandicota indica	Bandicot Rat	dhari indur												1	
Mus booduga	Field Mouse	metho indur												1	
Mus musculus	House Mouse	nengti indur												1	
Rattus rattus	Common House Rat	indur												1	
Family Soricidae															
Suncus murinus	Grey Musk Shrew	chika										x		1	

Name			IUCN						CITES			Wildlife Act		Current regional observations	
Scientific	English	Bangla	Ex	E	V	R	I	K	I	II	III	P	G	NERP	Other
Family Pteropodidae															
Cynopterus sphinx	Short-nosed Bat	bucha kola badur													P
Pteropus giganteus	Flying Fox	badur												1	
Family Megadermatidae															
Megaderma lyra	False Vampire	dhani badur												1	
Family Vespertilionidae															
Hespereptenus tickellii	Tickell's Bat	chamchicka													P
Pipistrellus coromandra	Indian Pipistrelle	khudi chamchika												1	
Order Cetacea															
Family Platanistidae															
Platanista gangetica	Freshwater Dolphin	shu shuk			x				x			x		1	
Order Carnivora															
Family Canidae															
Canis aureus	Jackal	pati shial												1	
Vulpes bengalensis	Bengal Fox	khek shial					x					x		2	
Family Herpestidae															
Herpestes autopunctatus	Small Indian Mongoose	beji, nakul										x		1	
Herpestes edwardsi	Common Mongoose	bara beji										x		1	
Family Mustelidae															
Lutra lutra monticola	Eurasian Otter	ud biral							x			x		2	
Lutra perspicillata perspicillata	Smooth Indian Otter	shosh dharia, jaat dharia						x		x		x		1	
Family Viverridae															
Viverra zibetha	Large Indian Civet	bagdash												1	
Viverricula indica	Small Indian Civet	khatash								x		x		1	

Name			IUCN						CITES			Wildlife Act		Current regional observations	
Scientific	English	Bangla	Ex	E	V	R	I	K	I	II	III	P	G	NERP	Other
Family Felidae															
Felis chaus	Jungle Cat	bon biral								x		x		2	
Felis viverrina	Fishing Cat	mecho biral								x		x		2	
Panthera pardus	Leopard	chita bagh		x					x			x			
Panthera tigris	Tiger	bagh		x					x			x			
Order Proboscidea															
Family Elephantidae															
Elephas maximus	Indian Elephant	hati		x					x			x		2	
Order Perissodactyla															
Family Rhinocerotidae															
Didermocoeros sumatrensis	Sumatran Rhinoceros	dui shinga gondar		x					x						
Rhinoceros sondiacus	Javan Rhinoceros	ek shinga gondar		x					x			x			
Rhinoceros unicornis	Great Indian Rhinoceros	ek shinga gondar		x					x						
Order Artiodactyla															
Family Suidae															
Sus salvinius	Pygmy Hog	khoday shukor		x					x						
Sus scrofa	Wild Boar	bonna shukor											x		
Family Bovidae															
Bos gaurus	Gaur	bon goru			x				x			x			
Bubalus bubalis	Wild Buffalo	bonna mahis		x								x			
Family Cervidae															
Axis porcinus	Hog Deer	natrini										x		3	
Cervus duvauceli	Swamp Deer	barosinga		x					x			x			
Cervus unicolor	Sambar	shambar										x		3	
CLASS REPTILIA															
Order Testudines															

Name			IUCN						CITES			Wildlife Act		Current regional observations	
Scientific	English	Bangla	Ex	E	V	R	I	K	I	II	III	P	G	NERP	Other
Family Emydidae															
Cuora ambionensis	Malayan Box Turtle	diba kasim													L
Geoclemys hamiltoni	Spotted Pond Turtle	kalo kasim					x		x			x		1	
Hardella thurjii	Brahminy Turtle	kali kaitta												1	
Kachuga dhongoka	Three Striped Roof Turtle	tinsira kachap													L
Kachuga smithii	Brown Roof Turtle	boro kari kaitta													L
Kachuga sylhetensis	Sylhet Roof Turtle	sylhet katua					x								L
Kachuga tecta tecta	Common Roof Turtle	kori kaitta							x				x	1	
Morenia petersi	Bengal Eyed Turtle	holday kaitta										x		1	
Family Trionychidae															
Aspideretes gangeticus	Ganges Soft Shell	khalua kasim							x			x		3	
Aspideretes hurum	Peacock Soft Shell	dhum kasim							x			x		1	
Chitra indica	Narrow-headed Soft Shell	sim kasim													R,L
Lissemys punctata punctata	Flapshelled Spotted Turtle	sundi kachap							x				x	1	
Order Sauria															
Family Gekkonidae															
Gekko gecko	Wall Lizard	tokkhak										x		1	
Hemidactylus brooki	House Lizard	tiktiki												1	
Hemidactylus frenatus	Common Lizard	tiktiki												1	
Family Agamidae															
Calotes versicolor	Garden Lizard	raktochusha												1	
Mabuya carinata	Common Skink	anjan												1	
Family Varanidae															
Varanus bengalensis	Bengal Grey Lizard	gui shap							x			x		1	
Varanus flavescens	Yellow Common Lizard	shona gui					x		x			x		1	

Name			IUCN						CITES			Wildlife Act		Current regional observations	
Scientific	English	Bangla	Ex	E	V	R	I	K	I	II	III	P	G	NERP	Other
Order Serpentes															
Family Pythonidae															
Python molurus molurus	Rock Python	ajogar, moyal			x				x			x			L
Family Dipradidae															
Lycodon jara	Yellow Wolf Snake	ghorginni													L
Pareas monticola	Assam Snail-eater	samukkhor													R
Family Natricidae															
Amphiesma stolata	Striped Keelback	dora shap													R
Atretium schistosum	Olive Keelback	mete shap												1	
Xenochrophis cerasogaster	Dark-bellied Marsh Snake	kalo mete dora													R
Xenochrophis piscator	Checkered Keelback	dhora shap												1	
Family Colubridae															
Ahaetulla nasutus	Common Vine Snake	laodoga												2	
Ptyas mucosus	Rat Snake	daraj												2	
Family Homalopsidae															
Cerberus rhynchops[1]	Dog-faced Water Snake	jalbora												1	
Enhydris enhydris	Smooth Water Snake	pyna shap												1	
Enhydris sieboldi	Siebold's Water Snake	pyna shap													L
Family Elaphidae															
Bungarus caeruleus	Common Krait	kal keotey												3	
Bungarus fasciatus	Banded Krait	shakini												2	
Naja naja kaouthia	Monocellate Cobra	gokhra												3	
Naja naja naja	Binocellate Cobra	khoia gokhra												2	
Order Crocodylia															
Family Crocodylidae															
Crocodylus palustris	Marsh Crocodile	kumir			x				x			x			

Name			IUCN						CITES			Wildlife Act		Current regional observations	
Scientific	English	Bangla	Ex	E	V	R	I	K	I	II	III	P	G	NERP	Other
CLASS AMPHIBIA															
Order Anura															
Family Bufonidae															
Bufo melanostictus	Common Toad	kuno bang												1	
Family Microhylidae															
Kaloula pulchra	Kaloula Frog	bhenpu bang												1	
Microhyla ornata	Ornate Frog	china bang												1	
Microhyla rubra	Red Microhylid	lal china bang												1	
Uperodon globolosum	Balloon Frog	phatka bang													L
Family Ranidae															
Rana cyanophlyctis	Skipper Frog	kotkote bang												1	
Rana limnocharis	Cricket Frog	jhi jhi bang											x	1	
Rana temporalis	Tree Frog	gecho bang												2	
Rana tigrina	Bull Frog	sona bang								x			x	1	
Rana tytleri	Tytler's Frog	pana bang												1	
Family Racophoridae															
Rhacophorus leucomystax	Tree Frog	gecho bang												1	
Rhacophorus maculatus	Maculated Tree Frog	gecho bang												1	
OVERALL TOTALS			0	10	4	0	5	1	21	6	0	31	5		
Families: 37															
Species: 89															
CURRENT TOTALS			0	1	2	0	5	1	10	6	0	22	4		
Families: 32															
Species: 77															

[1]Known to be anadromous in breeding habits, usually inhabits coastal brackish and saline waters.

Notes

Name
Scientific, English, and Bangla names of all species known or thought to have occurred in the lowlands (homestead and below) of the Northeast Region, rare visitors excepted.

IUCN
Global status as indicated in IUCN (1990). Coding:

- Ex Extinct
- E Endangered
- V Vulnerable
- R Rare
- I Indeterminate (known to be either Endangered, Vulnerable, or Rare)
- K Insufficiently known (suspected to be in one of the above categories)

CITES
Appendices I, II, and III to the Convention on International Trade in Endangered Species of Wild Flora and Fauna classify species as:

- I Species for which trading permits are never given
- II Species for which international trade is controlled
- III Species for which trade is controlled within (a) country, and the cooperation of other parties to the Convention is sought

Wildlife Act
Bangladesh Wildlife (Preservation) (Amendment) Act, 1974 lists 'game' (Schedule I, Part 1) and 'protected' animals (Schedule III):

- P protected
- G game

Current regional observations
Species observed (i) during NERP 1992-3 field surveys or (ii) other observers. Coding:

- 1 Direct encounter (seen), positive species identification
- 2 Contemporary species-specific physical evidence (nest, scat, etc.)
- 3 Recently captured live specimens
- R Reported to NERP team by local observers
- L Literature reports; recent NACOM sighting prior to NERP
- P Presumed present

Table B.3: Lowland plant species by community

Codes: Ex = Exotic; A = Annual; P = Perennial; H = Herb; S = Shrub; T = Tree; Tl = Treelet; C = Climber

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Submerged										
Aponogeton natans	Aponogetonaceae	ghechu			x	x				
Aponogeton undulatus	Aponogotonaceae	ghechu			x	x				
Aponogeton appendiculatus	Aponogetonaceae	ghechu			x	x				
Blyxa echinosperma	Hydrocharitaceae	shayala		x		x				
Ceratophyllum desmersum	Ceratophyllaceae	jhangi, katajhangi			x	x				
Ceratophyllum submersum	Ceratophyllaceae	jhangi			x	x				
Hydrilla verticillata	Hydrocharitaceae	kureli, jhangi			x	x				
Nachamendra alternifolia	Hydrocharitaceae	kaisa		x	x	x				
Myriophyllum tuberculatum	Haloraceae	--		x		x				
Myriophyllum tetrandrum	Haloraceae	--		x		x				
Najas sp.	Najadaceae	goisa		x		x				
Ottelia alismoides	Hydrocharitaceae	panikola, kaorali		x	x	x				
Potamogeton crispus	Potamogetonaceae	keorali		x	x	x				
Potamogeton pectinatus	Potamogetonaceae	keorali			x	x				
Potamogeton mucronatus	Potamogetonaceae	keorali			x	x				
Rotala rutundifolia	Lythraceae	--		x		x				
Rotala wallichii	Lythraceae	--		x		x				
Sagittaria guayanensis spp.*lappula*	Alismataceae	muamia, kaowathukri			x	x				
Sagittaria sagittifolia	Alismataceae	chhotokul			x	x				
Vallisnaria spiralis	Hydrocharitaceae	pataseola, bicha		x	x	x				
Free Floating										
Azolla pinnata	Salviniaceae	kutipana			x	x				
Eichhornia crassipes	Pontederiaceae	kochuripana			x	x				
Lemna perpusilla	Lemnaceae	khudipana			x	x				
Pistia stratiotes	Araceae	topapana			x	x				

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Salvinia cucullata	Salviniaceae	kuripana, indurkan			x	x				
Salvinia natans	Salviniaceae	tetulapana			x	x				
Spirodela punctata	Lemnaceae	khudipana			x	x				
Spirodela polyrhiza	Lemnaceae	khudipana			x	x				
Utricularia exoleata	Lentibulariaceae	chhotojhangi		x		x				
Utricularia aurea	Lentibulariaceae	chhotojhangi		x		x				
Utricularia stellaris	Lentibulariaceae	chhotojhangi			x	x				
Wolffia arrhiza	Lemnaceae	guripana			x	x				
Wolffia microscopica	Lemnaceae	guripana			x	x				
Rooted Floating										
Echinochloa colonum	Gramineae	parua		x	x	x				
Echinochloa sp.	Gramineae			x		x				
Eragrastis tenella	Gramineae	koni		x		x				
Euryale ferox	Nymphaeaceae	makhna		x	x	x				
Hygroryza aristata	Gramineae	phutki			x	x				
Leersia hexandra	Gramineae	--		x		x				
Limnophila indica	Scrophulariaceae	karpur		x		x				
Limnophila sessiliflora	Scrophulariaceae	bijatighash		x		x				
Limnophila heterophylla	Scrophulariaceae	karpur		x		x				
Mersilea quadrifoliata	Mersileaceae	sushnisak		x	x	x				
Nelumbo nucifera	Nymphaeaceae	padma			x	x				
Nymphaea stellata	Nymphaeaceae	nilshapla			x	x				
Nymphaea nouchali	Nymphaeaceae	sada, raktoshapla			x	x				
Nymphoides cristatum	Menyanthaceae	chandmala			x	x				
Nymphoides indicum	Menyanthaceae	panchuli			x	x				
Panicum paludosum	Gramineae	--		x		x				
Pseudoraphis spinescens	Gramineae	erali			x	x				
Pseudoraphis brunoninan	Gramineae	--			x	x				
Trapa maximowiczii	Trapaceae	singra, paniphal			x	x				

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Sedges & Meadows										
Aeschynomene aspera	Leguminosae	shola, banda		x			x			
Aeschynomene indica	Leguminosae	katshola, bhatshola		x			x			
Alternanthera philoxeroides	Amaranthaceae	helencha		x		x				
Arundo donax	Gramineae	baranal, gobanal		x		x				
Cleome hasslerana	Capparidaceae	nunirleta, hurhuri	x	x		x				
Clinogyne dichotoma	Marantaceae	sital-pati			x		x			
Colocasia esculenta	Araceae	kachu			x	x				
Cyperus sp.	Cyperaceae	mutha		x		x				
Eclipta alba	Compositae	kalokeshi, kalohuza		x	x	x				
Eleocharis dulcis	Cyperaceae	panichaise		x		x				
Enhydra fluctuans	Compositae	helencha, harhach			x	x				
Fimbristylis dichotoma	Cyperaceae	joina chaise			x	x				
Fimbristylis miliacea	Cyperaceae	joina, chatkighash		x		x				
Fimbristylis squarrosa	Cyperaceae	jumka chaich		x		x				
Hemarthria protensa	Gramineae	chailla		x		x				
Ipomoea aquatica	Convolvulaceae	kalmi shak			x	x				
Ipomoea fistulosa	Convolvulaceae	dhol kalmi	x		x		x			
Ludwigia abscendens	Onagraceae	kesardam, mulcha		x		x				
Ludwigia repens	Onagraceae	panidoga		x		x				
Monochoria hastata	Pontaderiaceae	baranukha, kechur			x	x				
Oryza rufipogon	Gramineae	jhara dhan		x		x				
Polygonum glabrum	Polygonaceae	bishkatali, kukra		x		x				
Polygonum stagninum	Polygonaceae	bishkatali, kukra		x		x				
Polygonum lanatum	Polygonaceae	kukra		x		x				
Polygonum pedunculare	Polygonaceae	kukra		x		x				
Polygonum barbatum	Polygonaceae	bishkatali		x		x				
Rumex dentata	Polygonaceae	bonpalong		x		x				
Setaria glauca	Gramineae	kulkulle, kauni		x		x				
Seteria fusca	Gramineae	pinginatchi		x		x				

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Schoenoplectus articulatus	Cyperaceae	--		x		x				
Scirpus juncoides	Cyperaceae	chisra			x	x				
Sclerostachya fusca	Gramineae	ekor,khuri		x		x				
Sesbania roxburghii	Leguminosae	huli, phuli		x			x			
Vetiveria zizanioides	Gramineae	binna, gandhabena			x	x				
Xanthium indicum	Compositae	ghagra, khagra		x		x				
Reeds										
Asclepias sp.	Asclepidiaceae				x					x
Asparagus racemosus	Liliaceae	satamuli, hilum			x		x			
Ficus heterophylla var. *heterophylla*	Moraceae	bonolat, baladumur			x		x			
Lippia javanica	Verbenaceae	bhuiokra			x		x			
Phragmites karka	Gramineae	khagra, nol			x		x			
Rosa involucrata	Rosaceae	gunja kata			x		x			
Saccharum spontaneum	Gramineae	khag, aisha			x		x			
Swamp Forest										
Barringtonia acutangula	Lecythidaceae	hijal			x			x		
Crataeva nurvala	Capparidaceae	barun			x			x		
Phyllanthus disticha	Euphorbiaceae	chitki			x		x			
Phyllanthus reticulatus	Euphorbiaceae	chitki			x		x			
Pongamia pinnata	Papilionoideae	karanch			x			x		
Salix tetrasperma	Salicaceae	bias, panihijal			x			x		
Trewia nudiflora	Euphorbiaceae	gotagamar, panidumur			x			x		
Crop Field										
Ageratum conyzoides	Compositae	fulkuri		x		x				
Alternanthera sessilis	Amaranthaceae	haicha, sachishak		x		x				
Amaranthus spinosus	Amaranthaceae	kata note		x		x				
Ceratopteris thalictroides	Parkeriaceae	--		x		x				
Chenopodium ambrosoides	Chenopodiaceae	chapali ghash		x		x				

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Coldenia procumbens	Boraginaceae	tripankhi		x		x				
Cotula hemispherica	Compositae	kancha ghash		x		x				
Croton bonplandianum	Euphorbiaceae	morchaagra, banjhal		x		x				
Cuscuta australis	Convolvulaceae	swarnalata		x						x
Cynodon dactylon	Gramineae	durba		x		x				
Cyperus cephalotes	Cyperaceae	niratraba		x	x	x				
Cyperus sp. (three species)	Cyperaceae	--		x		x				
Centipeda orbicularis	Compositae	machiti, hachuti		x		x				
Dentella repens	Rubiaceae	sadaphuli, sadajabri			x	x				
Digitaria longiflora	Gramineae	chota fulka		x	x	x				
Dipteracanthus prostratus	Acanthaceae	--		x		x				
Eleocharis atropurpurea	Cyperaceae	panichaise		x		x				
Eleusina indica	Gramineae	gaicha, chapre		x		x				
Ethulia conyzoides	Compositae	--		x		x				
Eupatorium odoratum	Compositae	assamlata	x		x	x				
Euphorbia sp.	Euphorbiaceae	--		x		x				
Glinus lotoides	Molluginaceae	alughas, kakdim		x		x				
Graphalium luteo-album	--	--								
Grangea maderaspatana	Compositae	nemuti, namuti		x		x				
Hedyotis sp.	Rubiaceae	--		x		x				
Heliotropium indicum	Boraginaceae	hatisur		x		x				
Herpestis monniera	Scrophulariaceae	brahmishak		x		x				
Hydrocotyle bupleuroides	Umbelliferae	--		x		x				
Hygrophila deformis	Acanthaceae	--		x		x				
Hygrophila polysperma	Acanthaceae	--		x		x				
Hyptes capitata	Labiatae	--		x		x				
Justicia gendarusa	Acanthaceae	nilnishinda		x		x				
Justicia simplex	Acanthaceae	--		x		x				
Lapidagathis sp.	--	--		x		x				
Leucas lavendulifolia	Labiatae	dron		x		x				

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Lindernia crustacea	Scrophulariaceae	bhui		x		x				
Ludwigia hyssopifolia	Onagraceae									
Mimosa pudica	Leguminosae	lajjabati	x		x	x				
Nicotiana plumbaginifolia	Solanaceae	bantamak		x		x				
Paspalum conjugatum	Gramineae	dadkuri			x	x				
Persicaria viscosa	Polygonaceae	lalkukra		x		x				
Polygonum plebejum	Polygonaceae	--		x		x				
Pogostemon stellatus	Labiatae	--		x		x				
Rottboellia protensa	Gramineae	barajati			x	x				
Rorippa indica	Cruciferae	bansarisha			x	x				
Rungia pectinata	Acanthaceae	pindi		x		x				
Sarcochlamys pulcherrima	--	brihati, karabi		x		x				
Scoparia dulcis	Scrophulariaceae	bandhundi	x	x		x				
Solanum khasianum	Solanaceae	phutibegun		x	x	x				
Solanum filicifolium	Solanaceae	titbegun			x		x			
Solanum nigrum	Solanaceae	kakmachi		x		x				
Solanum torvum	Solanaceae	gothdegun			x		x			
Solanum indicum	Solanaceae	phutibegun			x		x			
Spilanthes acmella	Compositae	marhatitiga		x		x				
Triumfetta rhomboides	Compositae	banokra		x		x				
Homestead										
Achyranthes aspera	Amaranthaceae	apang		x		x				
Aegle marmelos	Rutaceae	bel			x			x		
Alstonia scholaris	Apocunaceae	chatim			x			x		
Albizia sp.	Leguminosae	koroi			x			x		
Albizia procera	Leguminosae	sadakorai, silkorai			x			x		
Alpinia sp.	Zingiberaceae	tara			x	x				
Anthocephalus chinensis	Rubiaceae	kadom			x			x		
Aponomyxis polystachya	Meliaceae	ryana			x			x		
Ardisia sp.	Myrtaceae	narkoli			x				x	

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Areca catechu	Palmae	supari			x			x		
Areca triandra	Palmae	bangua			x			x		
Artocarpus heterophyllus	Moraceae	khatal			x			x		
Azadirachta indica	Meliaceae	nim			x			x		
Bombax ceiba	Bombacaceae	shimul			x			x		
Bambusa sp. (four species)	Gramineae	bans			x			x		
Borassus flabellifer	Palmae	tal			x			x		
Caesalpinia crista	Leguminosae	letkanta			x				x	
Calamus tenuis	Palmae	jalibet			x					x
Cassia occidentalis	Leguminosae	barahalkasunda			x		x			
Cassia siamea	Leguminosae	minjuri, eskikoroi			x			x		
Caryota urens	Palmae	bansupari, chaur			x			x		
Centella asitica	Umbelliferae	thankuni			x	x				
Chaetocarpus castanocarpus	Euphorbiaceae	bulkokra			x			x		
Citrus grandis	Rutaceae	jambura			x			x		
Cleorodendrum siphonanthus	Verbenaceae	bamanhati, banchat			x		x			
Cocos nucifera	Palmae	natrikal			x			x		
Crotalaria saltiana	Leguminosae	jhanjhani								
Diospyros perigrina	Ebenaceae	gab, deshigab			x			x		
Datura suaveolens	Solanaceae	rajghanta	x		x		x			
Erythrina variegata	Leguminosae	mander, piltamander			x			x		
Erythrina ovalifolia	Leguminosae	talimander			x			x		
Ficus benghalensis	Moraceae	bot			x			x		
Ficus rumphii	Moraceae	hijulia			x			x		
Ficus religiosa	Moraceae	assawath			x			x		
Ficus hispida	Moraceae	dumur			x				x	
Ficus sp.	Moraceae	chini bot			x			x		
Jasminum sp.	Oleaceae	--			x		x			
Lagerstromia speciosa	Lythraceae	jarul			x			x		

NAMES			Ex	Habit						
Scientific Name	Family	Local Name		A	P	H	S	T	Tl	C
Lantana camara var. *aculeata*	Verbenaceae	--	x		x		x			
Litsaea sp.	Lauraceae	--			x			x		
Mangifera indica	Anacardiaceae	am			x			x		
Melochia corchorifolia	Starculaceae	tikiokra			x			x		
Mikania scandens	Compositae	assamlata			x					x
Mikania cordata	Compositae	veratilata	x		x					x
Musa paradisiaca var. *sapientum*	Musaceae	kala			x				x	
Ocimum americanum	Labiatae	tulshi			x		x			
Pandanus sp.	Pandanaceae	keya			x		x			
Physalis minima	Solanaceae	bantepari		x		x				
Randia sp.	Rubiaceae	--			x				x	
Ricinus communi	Euphorbiaceae	reri, bheranda		x	x		x			
Samanea saman	Leguminosae	rendi, raintree	x		x			x		
Sapium indicum	Euphorbiaceae	harua,batul			x			x		
Syzygium fruticosa	Myrtaceae	khudijam			x				x	
Syzygium cumini	Myrtaceae	kalojam			x			x		
Terminalia catappa	Combretaceae	katbadam, deshibadam			x			x		
Temarindus indica	Leguminosae	tentul			x			x		
Torinia sp.	--	--			x			x		
Trichosanthes bracteata	Cucarbitaceae	makal			x			x		
Urena lobata	Malvaceae	--			x		x			
Zizyphus mauritiana	Rhamnaceae	boroi, kul			x				x	

Notes: Floodplain grassland community is composed of a mixture of species from the sedge-meadow and reed swamp communities.
Some field specimens (grasses) have not yet been identified.

ANNEX C

EXCERPTS FROM AQUACULTURE SYSTEMS

Excerpts taken from *Natural Systems for Waste Management and Treatment by Sherwood C. Reed, E. Joe Middlerbrooks and Ronald W. Crites. 1988, Mc Graw Hill, New York.*

Chapter

5

Aquaculture Systems

Aquaculture is defined as the use of aquatic plants or animals as a component in a wastewater treatment system. In many parts of the world wastewater is used for the production of fish or other forms of aquatic biomass in aquaculture operations. Some degree of wastewater renovation may occur in these cases but it is not the primary intent. The major focus in this chapter is on those systems where wastewater treatment is the functional intent of the operation.

Aquaculture treatment systems can utilize one major type of plant or animal in a monoculture operation, or use a variety of plants and animals in a polyculture operation. Both marine (seawater) and freshwater concepts have been tested. The major biological components include: floating plants, fish and other animals, planktonic organisms, and submerged plants. Emergent plants are also used, but these are more characteristic of wetland systems and are discussed in Chap. 6.

The treatment responses in an aquaculture system are due either to the direct uptake of material by the plants or animals and by the presence of these biota altering the physical environment in the system, or, as in the case of water hyacinths, the plant roots' acting as the host substrate for attached microbial organisms which provide a very significant degree of treatment. All of these plants and animals have specific environmental requirements that must be maintained for their successful use, and in most cases a regular harvest is necessary to ensure optimum performance. Performance expectations for these systems are listed in Table 1.1 in Chap. 1 and elsewhere in this chapter.

5.1 Floating Plants

Aquatic plants have the same basic nutritional requirements as plants growing on land and are influenced by many of the same environmental factors. The floating aquatic plants with the greatest known potential for wastewater treatment include water hyacinths, duckweeds, pennywort, and water ferns. Table 5.1 provides information on distribution of these plants in the United States and some of the critical environmental requirements. Hyacinths, pennywort, and duckweeds are the only varieties tested to date with wastewater, in pilot or full-scale systems.

Water hyacinths

Water hyacinth (*eichhornia crassipes*) is a perennial, freshwater aquatic macrophyte (water tolerant vascular plant) with rounded, upright, shiny green leaves and spikes of lavender flowers. The morphology of a typical hyacinth plant is shown in Fig. 5.1.

The petioles of the plant are spongy with many air spaces and contribute to the buoyancy of the hyacinth plant. The size varies with habitat. The root length will vary with the nutrient status of the water and the frequency of plant harvest. In nutrient-rich wastewaters with regular harvests the roots might extend 10 cm (4 in) below the central rhizome. If harvests are not performed the roots can grow and penetrate the substrate in unlined basins. The plant will also grow in moist soils. When grown in wastewater individual plants range from 50 to 120 cm (20 to 47 in) from the top of the flower to the root tips.

The hyacinth flower produces seeds but the principal means of reproduction is via offshoots (stolons) from the underwater rhizome, as shown on Fig. 5.1, which result in an interconnected, dense mat of plants on the water surface. The plants spread laterally until the water surface is covered and then the vertical growth increases. Hyacinths are one of the most productive photosynthetic plants in the world. It has been estimated that 10 plants could produce 600,000 more during an 8 month growing season and completely cover 0.4 ha (1 acre) of a natural freshwater surface.[19] The rate can be even higher in wastewater ponds. Wolverton has estimated a productivity of 140 metric tons/(ha · year) [154 ton/(acre · year)] for hyacinths grown in wastewater ponds.[32] This very rapid growth is the reason that hyacinths are a serious nuisance problem in southern waterways, but these same attributes become an advantage when used in a wastewater treatment

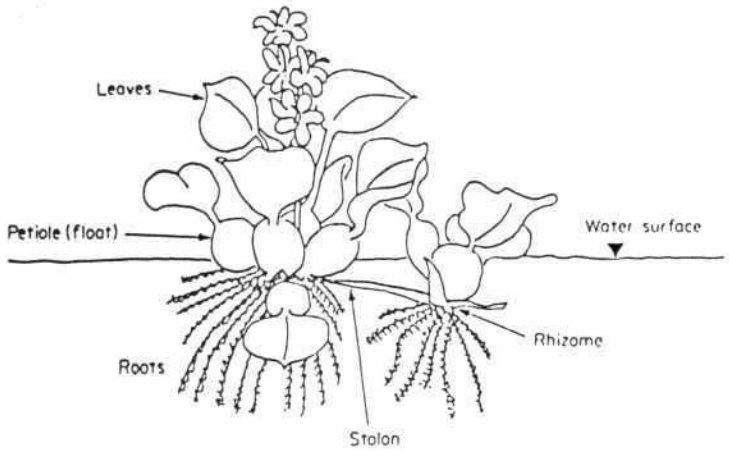

Figure 5.1 Morphology of the hyacinth plant.

system. Because of its history as a nuisance weed the interstate transport of hyacinth plants is prohibited by federal law.

The roots, petioles, flower stalks, and stolons all originate at the basal rhizome. Under freezing conditions the leaves and flowers will die and may expose the upper tip of the rhizome. The plant can regenerate from an undamaged rhizome but if the tip freezes the entire plant will die. This sensitivity to low temperatures is the major factor limiting the natural range of the hyacinth plant and its use in unprotected wastewater treatment facilities. Fig. 2.1 defines the areas suitable for unprotected wastewater treatment systems using hyacinths. Short-term summer use might be possible further north than shown on Fig. 2.1 but this would require a greenhouse for culturing and protecting the plants during the remainder of the year. The protective shelters and heat that would be required to sustain a year-round operation north of the zones shown on Fig. 2.1 are probably not cost effective.[16]

The dry weight composition of water hyacinth plants removed from wastewater systems is given in Table 5.2. The major constituent of the bulk plant is water, comprising about 95 percent of the total mass. This very high water content is a significant factor in the economics of the various disposal/utilization options for the harvested plants.

Performance expectations. Water hyacinth systems are capable of removing high levels of biochemical oxygen demand (BOD), suspended solids (SS), metals, and nitrogen, and significant levels of trace organics. The treatment concept has been developed through extensive laboratory and pilot scale research as well as evaluation of full-scale facilities.

TABLE 5.2 Composition of Hyacinth Plants Grown In Wastewater

Constituent	Percent of dry weight	
	Average	Range
Crude protein	18.1	9.7–23.4
Fat	1.9	1.6–2.2
Fiber	18.6	17.1–19.5
Ash	16.6	11.1–20.4
Carbohydrate	44.8	36.9–51.6
Kjeldahl nitrogen (as N)	2.9	1.6–3.7
Phosphorus (as P)	0.6	0.3–0.9

Hyacinths can be used to upgrade existing systems or to produce secondary, advanced secondary, or tertiary effluents depending on the design loading rates and management practices used.

Hyacinths on the water surface of a pond create a totally different environmental condition in the water as compared to an exposed water surface. The dense canopy of leaves shades the surface and prevents algal growth. This in turn maintains the liquid pH at near neutral levels. The mass of plants on the surface also minimizes wind-induced turbulence and mixing, as well as surface reaeration, and moderates water temperature fluctuations. As a result, the near surface water tends to be low in oxygen and the benthic zone is usually anaerobic even in shallow ponds.

The plant can survive and grow in anaerobic waters since oxygen is transmitted from the leaves to the root mass. The attached biological growth on the root mass is similar to trickling filter and RBC slimes, but in this case the oxygen source (from the roots) is near the center of the mass rather than on the outside. Bacteria, fungi, predators, filter feeders, and detritovores have been reported in large numbers on and among the plant roots. Typical performance data from several systems are given in Table 5.3. The excellent performance of the Coral Springs, Florida system is believed to be in part due to the use of multiple cells and the shallow 38 cm (15 in) depth, which allows a greater portion of the contained wastewater to contact the root zone of the plants.

BOD removal. The removal of BOD in a hyacinth pond is caused by the same factors described in Chap. 4 for conventional stabilization ponds. Further, very significant treatment contributions can be ascribed to the attached growth on the plant roots. The efficiency of BOD removal will be directly related to the density of the plant cover and the depth of water in the system. At water depths of 1 to 2 m (3 to 6 ft) a BOD loading of about 6.7×10^{-4} kg/kg of wet plant mass per day has been recommended by Wolverton[31] when facultative pond ef-

fluent is applied to the hyacinth cells. Assuming 100 percent coverage of dense plants on the water surface this translates to a surface loading of about 225 kg/(ha · day) [200 lb/(acre · day)] BOD. At 80 percent surface coverage a loading of 140 kg/(ha · day) BOD has been recommended by Wolverton.[32]

Suspended solids removal. The removal of suspended solids occurs through entrapment in the plant root zone and by gravity sedimentation in the quiescent water beneath the surface mat of hyacinth plants. Due to the less turbulent water conditions, sedimentation will be more effective in a hyacinth pond than in a conventional pond with an open water surface. Another major contribution to solids control is the suppression of algae growth since the hyacinth plant shades the water surface and prevents passage of sunlight to the water column.

Nitrogen removal. Plant uptake, ammonia volatilization, and nitrification/denitrification all contribute to nitrogen removal in hyacinth systems. Plant uptake, with plant harvest, can be an important removal pathway but nitrogen removal rates far in excess of plant uptake levels have been observed in a number of systems. A typical plant growth rate of about 220 kg/(ha · day) [196 lb/(acre · day)] (dry weight) would account for about 10 kg/(ha · day) [8.9 lb/(acre · day)] of nitrogen. The nitrogen removal actually observed at a number of systems was about 19 kg/(ha · day) [17 lb/(acre · day)] when the nitrogen loading ranged from 9 to 42 kg/(ha · day) [8 to 37 lb/(acre · day)].[30] The major factor responsible for this additional removal is believed to be nitrification/denitrification. The nitrifier organisms can flourish attached to the hyacinth roots, which provide oxygen, while adjacent microsites and the benthic layer will provide the anaerobic conditions and the carbon sources needed for denitrification. Nitrification/denitrification is more likely at a relatively shallow depth because the bulk of the wastewater has the opportunity for contact with the hyacinth root zone.

Pilot scale experiments with hyacinths and other aquatic plants in shallow containers [53 cm (21 in) deep] showed that overall nitrogen removal follows a first-order reaction rate.[21] The nitrogen removal observed was a function of plant density and temperature as shown by Eq. 5.1 and the rate constants in Table 5.4.[21]

$$\frac{N_e}{N_0} = \exp[-kt] \tag{5.1}$$

where N_e = total nitrogen in system effluent, mg/L
N_0 = total nitrogen in applied wastewater, mg/L
k = rate constant, dependent on temperature and plant density, days^{-1} (see Table 5.5 for values)
t = detention time in system, days

TABLE 5.4 Rate Constants for Eq. 5.1

Temperature and plant density	k, days^{-1}
Summer months	
Mean temperature 27°C ± 1°C	
Plant density, kg/ha (dry weight)	
3,920	0.218
10,230	0.491
20,240	0.590
Winter months	
Mean temperature 14°C ± 4°C	
Plant density, kg/ha (dry weight)	
4,190	0.033
6,690	0.023
20,210	0.184

Equation 5.1 is similar in form to the equation in Table 4.7, which estimates the nitrogen removal in pond systems. Either Table 4.7 or 4.8 can be used to estimate the nitrogen removal due to volatilization in hyacinth ponds. The results are not additive to Eq. 5.1 since the equation calculates the overall nitrogen removal which already includes a component for volatilization.

An analysis of data from the hyacinth systems listed in Table 5.3, as well as other sources, indicates that a correlation exists between nitrogen removal and the hydraulic loading on the basin surface. The relationship is described with Eq. 5.2, which is valid for a moderately dense (80 percent or more of basin surface covered with hyacinths) stand of plants with regular harvests to maintain optimum growth.

$$L_N = \frac{760}{(1 - N_e/N_0)^{1.72}} \tag{5.2}$$

where L_N = hydraulic loading, limited by nitrogen removal, m^3/(ha · day)
N_e = nitrogen concentration required in system effluent, mg/L
N_0 = nitrogen concentration in influent to hyacinth basins, mg/L

In USCS units (L_N = million gals per day per acre) the equation becomes:

$$L_N = \frac{1}{(12.3)(1 - N_e/N_0)^{1.72}}$$

Phosphorus removal. The only significant removal pathway for phosphorus is plant uptake and that will usually not exceed 30 to 50 percent of the phosphorus present in typical municipal wastewaters. The removal will not even approach that range unless there is a careful vegetation management program involving frequent harvest. Maxi-

mum plant uptake of phosphorus may also require supplemental nitrogen fertilization since the ratio of nitrogen to phosphorus in typical wastewaters is significantly different from the balance required by the hyacinth plants (N:P = 6:1). As a result, there may be a nitrogen deficiency in the final basins of a hyacinth system and these plants cannot utilize the available phosphorus without additional nitrogen.

In typical systems where careful control and supplemental nutrients are not provided the phosphorus removal will probably not exceed 25 percent. Chemical precipitation with alum, ferric chloride, or other chemicals in a separate treatment step is recommended if high levels of phosphorus removal are a project requirement. Equation 5.3, derived from a number of operational systems can be used to estimate the potential for phosphorus removal in hyacinth basins. As with Eq. 5.2 it is valid when the basin surfaces are at least 80 percent covered with plants and there is a regular harvest.

$$L_p = (9353)\frac{P_e - 0.778P_0}{P_0 - P_e} \tag{5.3}$$

where L_p = hydraulic loading, limited by phosphorus removal, m³/(ha · day)
P_e = phosphorus concentration required in system effluent, mg/L
P_0 = phosphorus concentration in influent to hyacinth basins, mg/L
[m³/(ha · day)]/(9353) = million gal/(day · acre)

Metals removal. Hyacinth systems are capable of high levels of metal removal. Although plant uptake can be significant the principal mechanisms are believed to be chemical precipitation and adsorption on substrate and on the plant surfaces. Mature plants will begin to slough root matter so any adsorbed material will then become part of the detritus or benthic sludge. In a study in Texas, Dinges[7] found that metals concentration in the bottom sediments exceeded the concentration in the living hyacinth plant tissue by at least an order of magnitude. This sediment consisted of a 2-year accumulation of biological solids as well as dead and sloughed plant material. The removal of trace minerals observed in a 28-day batch experiment and in a 15-day continuous flow experiment are compared in Table 5.5.

TABLE 5.5 Trace Element Removal by Water Hyacinths[14]

	Percent removal			
	With hyacinths		Without hyacinths	
Parameter	Batch	Continuous flow	Batch	Continuous flow
Arsenic	12	41	4	23
Boron	12	36	1	—
Cadmium	69	85	23	39
Mercury	70	92	60	93
Selenium	8	60	0	21

Removal of trace organics. The removal of some organic priority pollutants has been measured in a pilot scale hyacinth basin system in San Diego, California. The hyacinth units in this case were used as a preliminary step ahead of ultrafiltration, reverse osmosis, carbon adsorption, and disinfection in a process intended to demonstrate the capability for complete water recycle and reuse. As shown on Table 5.6 excellent removal of trace organics was demonstrated in these hyacinth basins. The removal of trace organics is believed to be primarily due to decomposition of the compounds by bacterial action, although the plant itself can take up significant quantities of these materials.

Design considerations. Hyacinth systems can be designed for treatment of raw wastewater, primary effluent, upgrading of existing secondary treatment systems, or for advanced secondary or even tertiary treatment. As with other pond systems, the critical design parameter is the organic loading on the system.

If the project goal is secondary treatment the system design is essentially the same as given in Chap. 4 for a facultative pond. Table 5.7 presents a summary of the appropriate engineering criteria when hyacinths are used. The major function of the hyacinth plants in this case is the surface cover provided by the floating vegetation. This will

TABLE 5.6 Trace Organic Removal in Hyacinth Basins*

	Concentration, µg/L	
Parameter	Untreated wastewater	Hyacinth effluent*
Benzene	2.0	ND†
Toulene	6.3	ND
Ethylbenzene	3.3	ND
Chlorobenzene	1.1	ND
Chloroform	4.7	0.3
Chlorodibromomethane	5.7	ND
1,1,1 Trichloroethane	4.4	ND
Tetrachloroethylene	4.7	0.4
Phenol	6.2	1.2
Butylbenzyl phthalate	2.1	0.4
Diethyl phthalate	0.8	0.2
Isophorone	0.3	0.1
Naphthalane	0.7	0.1
1,4 Dichlorobenzene	1.1	ND

* Pilot scale system, 4.5 day detention time, 76 m³/day flow, three sets of two basins each, in parallel, plant density 10–25 kg/m² (wet weight).
† ND = not detected.

TABLE 5.7 Suggested Criteria for Secondary Treatment with Hyacinth Ponds

Factor	Criterion
Effluent requirements	BOD <30 mg/L, SS <30 mg/L
Wastewater input	Untreated
Organic loading	
Entire system surface	50 kg/(ha · day) [45 lb/(acre · day)] BOD
First cell in system	100 kg/(ha · day) [90 lb/(acre · day)] BOD
Water depth	<1.5 m (5 ft)
Maximum area, single basin	0.4 ha (1 acre)
Total detention time	>40 days
Hydraulic loading	+200 m³/(ha · day) [21,600 gal/(acre · day)]
Water temperature	>10°C (>50°F)
Basin shape	Rectangular, L:W > 3:1
Influent flow diffusers	Recommended
Mosquito control	Necessary
Harvest schedule	Seasonal or annual
Multiple cells	Essential, 2 sets of 3 basins, each recommended

prevent algal growth and contribute to BOD and SS removal. The performance of the hyacinth system will be significantly better than a comparable-sized facultative pond with an open water surface. In addition to new designs, hyacinth plants can be added to the final cells in existing facultative ponds to upgrade effluent quality to acceptable levels.

Multiple cells in pond systems are essential for proper hydraulic control (as described in Chap. 4), and are also important in hyacinth systems to ensure effluent quality during harvesting and other maintenance operations. A conservative approach to design, given in Table 5.7, divides the total treatment area required into two interconnected parallel rows of basins, with at least three basins in each set. This will allow temporary flow diversion for maintenance without disruption of overall performance.

Some states require the design of duplicate hyacinth systems, each capable of treating the design flow. It is therefore necessary to check with the appropriate regulatory authorities before proceeding with final project design.

Suggested engineering criteria for advanced secondary treatment using hyacinth ponds are given in Table 5.8. It is assumed in this case that at least primary treatment has been provided in a preliminary step. This could be achieved with a suitable aerobic or anaerobic pond, with conventional primary treatment, or with an Imhoff tank for small communities. It has been shown to be cost effective to provide supplemental aeration in these hyacinth systems to accelerate the treatment and allow increased loadings and shorter detention times. If aeration is not provided, the organic loadings should not exceed the values given

TABLE 5.8 Suggested Criteria for Advanced Secondary Treatment with Hyacinth Ponds

Factor	Criterion
Effluent requirements	BOD <10 mg/L, SS <10 mg/L, some nitrogen removal
Wastewater input	Equivalent to primary
Organic loading	
Entire system surface	100 kg/ha · day) [90 lb/(acre · day)] BOD
First cell surface	300 kg/(ha · day) [270 lb/(acre · day)] BOD
Detention time	>6 days
Aeration requirements	Design as partial mix aerated pond to meet O_2 needs (see Chap. 4), use submerged diffused aeration in first two cells of each set.
Water temperature	>20°C (68°F)
Water depth	<0.9 m (3 ft)
Hydraulic loading	<800 m³/(ha · day) [86,500 gal/(acre · day)]
Basin shape	Rectangular, L:W > 3:1
Influent flow diffuser	Essential
Effluent collection manifold	Essential
Single basin area	<0.4 ha (1 acre)
Mosquito control	Necessary
Harvest schedule	>monthly
Multiple cells	Essential, 2 interconnected parallel sets of 3 basins each

in Table 5.7. The shallower depth used in this case also allows the hyacinth plant to contribute more effectively to treatment than in the previous case. A tertiary hyacinth system, primarily for nutrient removal, can be an add-on to the system described in Table 5.7 or to any other secondary treatment process. Typical engineering criteria are described in Table 5.9. The use of the criteria in these tables is illustrated in the design examples that follow.

Example 5.1. Design a hyacinth system to produce secondary effluent with an untreated municipal wastewater as influent. Assume: design flow rate = 760 m³/day; wastewater characteristics are BOD_5 = 240 mg/L, SS = 250 mg/L, TN = 25 mg/L, TP = 15 mg/L; and critical winter temperature >20°C (68°F). Effluent requirements: BOD_5 = <30 mg/L, SS <30 mg/L.

solution

1. Determine BOD loading:

$$(240\ mg/L)(760\ m^3/day)(10^3\ L/m^3)(1\ kg/10^6\ mg) = 182.4\ kg/day$$

2. Determine basin surface areas based on criteria in Table 5.7: 50 kg/(ha · day) BOD for entire area, 100 kg/(ha · day) BOD for first cell.

$$\text{Total area required} = \frac{182.4\ kg/day}{50\ kg/(ha \cdot day)} = 3.65\ ha$$

$$\text{Surface area of first cells} = \frac{182.4\ kg/day}{100\ kg/(ha \cdot day)} = 1.82\ ha$$

Structural elements. The small individual basins suggested in Tables 5.7 to 5.9 are recommended to facilitate harvesting of the hyacinth plants at small to moderate sized systems. The long narrow configuration suggested is for hydraulic control and ease of harvesting. The width of the basin will depend on the capabilities of the harvesting equipment. If the system is drained on an annual basis for plant removal, an access ramp is needed in each basin; the basin width being not especially critical since a front end loader or similar equipment can be used for basin cleaning. The higher rate systems with more frequent harvests require access for floating devices or they must have roads on the dikes for equipment access. A typical drag-line bucket might have a 9-m (30-ft) range so a basin might be 15 to 18 m (50 to 60 ft) wide and designed for harvesting from both sides.

The use of multiple influent points is recommended for secondary systems and is essential for the higher rate, high performance systems. This is to ensure proper wastewater distribution and effective use of the entire treatment volume and to maintain aerobic conditions throughout the basin. Sprinklers can also be used for influent distribution and have the added advantage of providing some frost protection during cold weather periods. Experience with long rectangular hyacinth cells with a single inlet has demonstrated that most of the solids and BOD removal occur near the headworks. This can create undesirable anaerobic conditions in this area which can result in odor problems and ineffective mosquito control as well as being an ineffective use of the total treatment volume. The influent works should be designed to uniformly apply wastewater over the initial ¼ to ½ of the surface area in the first hyacinth covered basin in each set, when the basins are square or rectangular. Other inlet/outlet configurations, suggested by Tchobanoglous[28] to ensure better utilization of the basin area, are shown in Fig. 5.2.

An effluent manifold spanning the entire basin width in the typical rectangular cells is also recommended to avoid "dead" spots and the resulting ineffective treatment near the outlet. These manifolds are suggested for interbasin transfer and for the final effluent discharge. An alternative, as shown in Fig. 5.3 is to narrow the channel width as the outlet point is approached. This will serve to increase the flow velocity toward the outlet and thereby eliminate the "dead" spots. These manifolds or single discharge points should be at the water surface in all of the basins to ensure that all water is brought up into contact with the hyacinth roots prior to discharge. In relatively wide basins changing the width near the outlet will not be effective. The approach in this case, as shown in Fig. 5.3, is to slope the basin bottom upward in the discharge zone to create a shallow depth to ensure contact with the plants. Screening or a baffle is necessary ahead of the manifold or outlet to prevent loss of hyacinth plants with the effluent.

Long narrow channels can be constructed with concrete or other structural sidewalls and a lined bottom. The construction of wider basins is essentially the same as the pond systems described in Chap. 4. Exterior dikes should be about 3 m (10 ft) wide at the top to permit vehicle movement; side slopes should be 3:1 and the dike constructed to provide about 0.5 m (1.6 ft) of freeboard above the design water surface.

State or local regulations will control the degree of permeability allowed in the basin bottom. It is likely that lining or some other impermeable barrier will be required in most cases if permeable soils are dominant on the site (see Sec. 4.12 for further discussion). The bottom of the basin should be smooth and constructed at a slight grade (0.5 percent) toward the outlet to facilitate drainage. Construction of a sump in the outlet area is also suggested for the same purpose.

The optimum water depth in a hyacinth basin depends on the intended function of the vegetation and on the desired effluent quality. The depth is not critical if the major purpose of the hyacinth plant is surface shading to prevent algae growth. A relatively shallow depth is desirable when the plants are expected to provide significant nutrient removal. The optimum water depth in a carefully managed high-rate system might range from 0.3 m (1 ft) in the first basin to 0.45 m (1.5 ft) in the final basins. A greater depth is used in the final cell since the hyacinth roots will be longer when fewer nutrients are present in the water. The discharge zone in these final basins might then be reduced to the 0.15 m (0.5 ft) shown in Fig. 5.3 to ensure full contact with the plants prior to final discharge. A design using these shallow depths (0.3 to 0.5 m) should be able to reduce the maximum design detention times given in Tables 5.8 and 5.9. A pilot scale test is suggested for large scale projects to optimize these design parameters.

Operation and maintenance. The major operational concerns are control of mosquitos and odors, vegetation management, sludge removal, plant harvest, and the disposal or utilization of the harvested materials and sludge. Other requirements include all of the routine activities common to the operation and maintenance of pond systems, which are the same for hyacinth systems and the lagoons described in Chap. 4.

A special concern with hyacinth ponds is the potential for significantly higher evapotranspiration (ET) from the plants as compared to evaporation from an open water surface under the same climatic conditions. Several research efforts have shown the ET rates for hyacinths are about 3 times the evaporation rate for open water.[22] The ET losses calculated for hyacinth basins at Kissimmee, Florida were about 20 to

33 L/(m² · day) [0.5 to 0.8 gal/(day · ft²), which was about 3 times the expected pan evaporation rate for the area.[1] This can be a critical factor when hyacinth systems are planned for arid climates where excessive water losses are not desirable.

Mosquito control. Control with chemical sprays is not practical because the mosquito larvae in hyacinth ponds are at the water surface beneath the leaf canopy. Several pilot systems in California were closed because of mosquito problems. An effective control method is to stock each basin with *Gambusia* or similar small surface feeding fish that prey on the mosquito larvae. These fish will not tolerate anaerobic conditions and will not enter water zones with low oxygen levels. Avoiding such anoxic conditions near the basin inlets is one of the reasons for installing influent diffusers. These small tropical fish will not tolerate low water temperatures either. If a seasonal hyacinth operation is planned it will be necessary to restock the basins with both plants and fish at the start of the warm weather period. A typical initial stocking rate for the *Gambusia* fish is about 7000 to 12,500/ha (2800 to 5000/acre) of surface area. Other species used for mosquito control include goldfish (*Carassius auratus*), frogs (*Hyla* sp.), and grass shrimp (*Palemonetes kadiakensis*). If algae control is necessary, Blue Tilapia (*Tilapia aureaus*), Sailfin Mollies (*Poccilia latipinna*), and Japanese Koi (*Cyprinus* sp.) can be used. The hyacinth basins in the system constructed at Austin, Texas incorporate small fenced-off zones to maintain an open water surface and sufficient aeration from natural sources to support the *Gambusia* fish.[8] The basins should be stocked with fish a few weeks prior to stocking with the hyacinth plants.

Odor control. Since the floating mat of plants suppresses algae and prevents wind-induced surface reaeration the only source of oxygen is from the phytosynthetic respiration of the hyacinth plants. In unaerated basins this natural source of oxygen will not be enough to sustain general aerobic conditions with moderate to high BOD loadings. If the wastewater contains more than 30 mg/L sulfates, the anaerobic conditions will probably result in objectionable hydrogen sulfide odors. This is another reason for the broad distribution of the influent in at least the first basin in a hyacinth system. Supplemental aeration for odor control may still be necessary in these primary basins at night and during other phytosynthetically inactive periods.

Vegetation management. The degree of vegetation management required depends on the water quality goals of the project and a choice between harvesting plants or frequent sludge removal. A frequent plant harvest may be necessary to sustain a significant level of phosphorus removal but is not necessary for nitrogen removal. Studies in Florida have shown nitrogen removal rates to be 2 to 3 times higher in unharvested basins as compared to frequently harvested ones.

When the plant density on the water surface exceeds about 25 kg/m² (5 lb/ft²) (wet weight) sloughing of root material commences. This accumulation of plant detritus on the basin bottom will, after a few months, exceed the mass of settled wastewater solids. One approach, recommended by the State of Texas, uses an annual draining and cleaning of each basin instead of regular plant harvest. All of the plants as well as the benthic sludge are removed and the basin is then refilled and restocked with new plants. Systems in Florida and elsewhere have adopted a more frequent plant harvest and a less frequent basin cleaning.

Frequent harvests are considered necessary to keep the plants at the optimum growth stage to ensure optimum phosphorus removal. In these cases, the plant density is maintained between 10 and 25 kg/m² (2 and 5 lb/ft²) (wet weight). One technique for monitoring plant density is to use mesh bottomed floating baskets about 1 m on a side. The basket is periodically lifted out of the basin and weighed to determine the wet weight density of the plant cover. System designs based on Wolverton's research[31-33] recommend wet weight plant densities from 12 to 22 kg/m² (2.5 to 4.6 lb/ft²) for optimum treatment with loosely packed plants with 80 to 100 percent surface coverage. An initial plant stocking rate of 1.8 kg/m² (0.37 lb/ft²) has been used in Florida.[1]

Nutrient and micronutrient deficiencies have also been observed in the final basins of hyacinth systems. Plant chlorosis (leaf yellowing) due to iron deficiency has occurred in several systems in Florida. The problem was corrected with the addition of ferrous sulfate at a rate sufficient to maintain the iron concentration in the water at about 0.3 mg/L.

Insect infestations can cause major damage to the plants. The caterpillar stage of the moth *Sameodes allijuttales* and the weevils *Neochetina eichornia* and *N. bruchi* attack the plant stolon and the leaves, respectively. The weevils seem to be more active when the plants are under density stress and the moths are more likely to be a problem with hot, dry weather conditions. The life cycle for the weevils is about 60 days, with peaks in the spring and fall. Spot harvests may be an effective control in the early stages, and the insecticide Sevin has been used for major infestations.[15]

The hyacinth plant does not tolerate cold, and even short periods of freezing weather can destroy this important component in the treatment process. The 1.6-ha (4-acre) hyacinth system in Austin, Texas is entirely covered with a greenhouse structure to permit year-round operation. Other plant types are also being investigated for combined

use with hyacinths. One possibility is the pennywort (*Hydrocotyle umbellata*), which is more cold tolerant than the hyacinth and also has a higher oxygen transfer rate to the root zone. Combined hyacinth-pennywort systems in Florida perform better and more reliably than monoculture units with either of the plants.[5]

Sludge removal. The benthic sludge consisting of wastewater solids and plant detritus must eventually be removed from all hyacinth systems. An annual cleaning of the primary cells in very shallow high-rate systems may be needed even with frequent harvests. The secondary and tertiary cells in these systems may only need cleaning every 2 to 3 years. The deeper hyacinth systems with regular harvest, which are designed for secondary treatment only, should be cleaned on a 5-year cycle. Systems with no harvest, or those operated on a seasonal basis should be cleaned on an annual basis. The cleaning method will depend on the basin configuration and its construction materials. Large basins constructed of compacted earth, concrete, asphalt, or protected membrane liners could use conventional front-end loaders for sludge removal from the drained basins. Small basins could use float-supported suction pumps or dredges. Since the sludge will contain wastewater solids, its subsequent treatment and disposal must comply with local regulatory practices.

Harvest procedures. The harvest frequency may range from a few weeks to a month or more depending on the level of nutrient removal required. If a complete harvest is needed for insect control, frost damage, or other reasons, restocking at a density of about 7 kg/m^2 (1.5 lb/ft^2) (wet weight) will promote optimum growth and rapid coverage of the basin.[15]

A number of methods have been tried for harvest of the hyacinth plants including front-end loaders, draglines or backhoes equipped with clamshell buckets or weed buckets, conveyors, conveyor-chopper systems, chopper pumps, rakes, and boats. The equipment selected should be able to easily reach any part of the hyacinth basins to allow selective harvests of mature plants. Wolverton[33] compared conveyor-choppers, a conveyor with a pusher boat, and a dragline equipped with a modified clamshell bucket. The conveyor-pusher boat and the dragline had about the same production rates: 418 m^2/h (4500 ft^2/h) with a plant density of about 22 kg (wet wt)/m^2. The dragline was recommended for its greater mobility and reliability. Modified truck or tractor mounted backhoe devices have also been successfully used. Instead of the normal bucket attachment basketlike tines are placed at the end of the articulating arm. These devices are suitable for small- to moderate-sized systems with channel-type designs. The limiting factor for the economics of the operation is the cost of transport from the basin to the disposal/utilization site. A typical 12 m^3 (16 yd^3) dump truck can hold about 5 to 7 metric tons (6 to 8 tons) of wet hyacinth plants.

Larger scale systems designed for both wastwater treatment and for biogas production will require in-basin harvesting techniques and a more efficient transport system than the trucks used at the smaller operations. Recent developments in Florida utilize winch-operated floats or a floating pusher vehicle to move the plants to the onshore chopper and progressive cavity pump, which can then deliver the chopped plants as a slurry (about 4 percent) solids directly to the biogas digestor. This equipment can harvest 9 metric tons (10 tons) of plants per hour at an approximate cost of $2.00/metric ton ($2.30/ton).

The hyacinth system in Coral Springs, Florida[27] reports the best effluent water quality performance with "loosely packed" hyacinths on the water surface. A four-week harvest schedule is used and not more than 15 to 20 percent of the plants are taken at one time. A truck-mounted dragline with a weed bucket is used, with a dump truck for transport of the harvested material. A production rate of 700 m^2 (7300 ft^2) per hour was reported with this equipment. The harvest was reported in volumetric units and was 2.7 m^3 per 100 m^2 of basin surface (3.5 yd^3/1000 ft^2). If a plant surface density of 22 kg/m^2 (4.6 lb/ft^2) is assumed, the wet unit weight of the harvested plants would have been about 815 kg/m^3 (51 lb/ft^3).

Hyacinth disposal or utilization. Since the hyacinth plants are about 95 percent water, an intermediate drying step is usually employed prior to disposal or utilization of the harvested material at the smaller systems. Preliminary grinding, chopping, and pressing have been tried to accelerate the drying process. Covered solar drying racks have also been used, but the most common approach is to use a small open area adjacent to the basins for spreading and air drying of the whole harvested plants to the desired moisture content. The solar drying racks used in Florida have a 5-day drying cycle to reach a moisture content of 20 percent,[26] while an open bed might require 2 to 3 weeks to reach the same level in the same climate.

The dried plants can be disposed of in a landfill, or elsewhere, as permitted by the local regulatory authorities. If the wastewater has very high metal concentrations it may be advisable to check the metal content of the dried plant to ensure that the levels do not exceed permit allowances for disposal/utilization (see Chap. 8 for further discussion of these limits).

The simplest approach for beneficial reuse of the harvested materials is to compost the semidry hyacinths and then use that material as a soil conditioner/fertilizer. Anaerobic digestion of the plants and sludge for methane production and processing of the plants for animal feed

have been shown to be technically feasible but marginally cost effective. Recent demonstrations in Florida using a 2:1 mixture of hyacinths and sludge in a vertical flow nonmixed anaerobic reactor have produced high quality methane in a cost-effective process.[17] The major factor is the novel reactor design which does not require the mixing energy used in conventional anaerobic digestors. There may not be sufficient plant production to sustain routine operation of these more complex processes at wastewater flows less than 3800 m^3/day (1 million gallons/day). The composting option is the best-suited option for smaller systems.

Duckweed

Duckweed, in the genera *Lemna* sp., *Spirodela* sp., and *Wolffia* sp., have all been tested for pollutant removal or used in wastewater treatment systems. These are all small, green freshwater plants with a leaflike frond a few millimeters in width with a short root usually less than a centimeter in length. The morphology of the plant is shown on Fig. 5.4.

These duckweeds are the smallest and the simplest of the flowering plants and have one of the fastest reproduction rates. A small cell in the frond divides and produces a new frond; each frond is capable of producing at least 10 to 20 more during its life cycle.[12] *Lemna* sp. grown in wastewater effluent (at 27°C) doubles in frond numbers, and therefore the area covered, every 4 days. It is believed that duckweed can grow at least twice as fast as other vascular plants. The plant is essentially all metabolically active cells with very little structural fiber.

Duckweed, like hyacinths, contains about 95 percent water; the composition of the plant tissue is given in Table 5.10. A comparison of the values in Tables 5.10 and 5.2 indicate that duckweed contains at least twice as much protein, fat, nitrogen, and phosphorus as hyacinth. Several nutritional studies have confirmed the value of duckweed as a food source for a variety of birds and animals.[12]

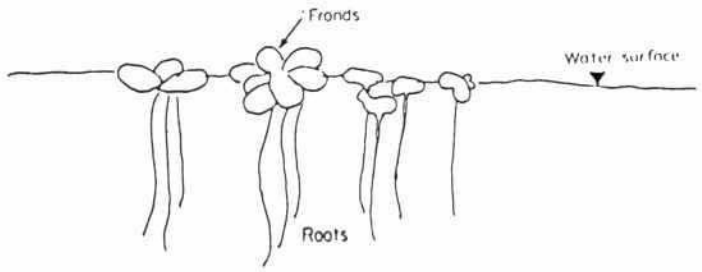

Figure 5.4 Morphology of duckweed plants.

TABLE 5.10 Composition of Duckweeds Grown In Wastewater[13]

Constituent	Percent of dry weight	
	Range	Average
Crude protein	32.7–44.7	38.7
Fat	3.0–6.7	4.9
Fiber	7.3–13.5	9.4
Ash	12.0–20.3	15.0
Carbohydrate	—	35.0
Kjeldahl nitrogen (as N)	4.59–7.15	5.91
Phosphorus (as P)	0.80–1.8	1.37

Duckweeds are more cold tolerant than hyacinths and are found throughout the world. A minimum temperature of 7°C (45°F) has been suggested as the practical limit for growth of duckweeds.[16] As shown in Fig. 5.5 the range for a year-round duckweed treatment system is slightly greater than shown in Fig. 2.1 for hyacinths, but seasonal duckweed systems operating 6 months per year should be possible for most of the United States.

Performance expectations. Duckweed systems are capable of high levels of BOD and SS removal and significant levels of metal and nutrient removal. As compared to hyacinths the duckweed plant plays a less direct role in treatment due to its small size. The lack of an extensive root zone provides very little substrate for attached microbial growth. A number of studies have used wastewater to produce duckweed for animal feed[7] but there is very limited experience to date using the plants as a component in a system designed primarily for wastewater treatment.

The growing plants will form a single layer completely covering the water surface, then some species will grow on top of others. Their small size makes the plants susceptible to the wind; initially this may result in part of the basin being uncovered but the long-term effect is a thick mat of plants covering the entire basin. This mat is still susceptible to the wind, so floating booms or cells are usually used to hold the plants in place. The formation of this mat is probably the most significant contribution of the duckweed plant to wastewater treatment. This surface cover prevents algae growth, stabilizes pH, and enhances sedimentation but is also likely to result in anaerobic conditions due to the relatively low phytosynthetic oxygen production from the small plants. The plant can flourish under anoxic conditions but the rate of

biological activity in the water will proceed at lesser rates than in an aerobic environment.

BOD removal. The major factors responsible for BOD removal in a duckweed system are the same as described in Chap. 4 for facultative stabilization ponds. The duckweed plants create the environment for treatment but contribute very little directly to the removal of BOD. Wolverton[33] has reported on the performance of a duckweed-covered basin (following an aerated cell) near Biloxi, Mississippi. The organic loading on this 22-day detention time basin was about 24 kg/(ha · day) [21 lb/(acre · day)], which is near the low end of the range for conventional facultative ponds. The final effluent from this basin contained about 15 mg/L of BOD and was anaerobic.

Suspended solids removal. The removal of suspended solids in duckweed basins is due to the same factors described above for BOD removal. Suspended solids removal in a duckweed-covered basin should be more effective as compared to a conventional stabilization pond due to the lack of algae and the improved quiescent conditions under the surface mat. The final SS concentration from the Cedar Lake system discussed in the previous section averaged 14 mg/L.

Nitrogen removal. Plant uptake, ammonia volatilization, and nitrification/denitrification are believed to contribute to nitrogen removal in a duckweed basin. Laboratory scale experiments indicate the plants contribute significantly but only account for about 25 percent of the nitrogen removed in the system.[21] Other experiments at the same scale [water depth 41 cm (16 in)] indicate that overall nitrogen removal follows a first-order reaction rate.[20] The nitrogen removal was influenced by the plant species, the plant density, and the temperature. Equation 5.1, with the rate constants in Table 5.11, can be used to estimate overall nitrogen removal in a duckweed system. Frequent harvests are necessary to sustain high levels of nitrogen removal. Since the duckweed plant has essentially no root zone the nitrification/denitrification reactions described previously for hyacinths cannot occur in these systems.

Phosphorus removal. Data from small-scale laboratory studies in Florida indicate that plant uptake by duckweed was responsible for about 30 percent of the phosphorus removed in the summer and only 10 percent during the winter.[21] If significant phosphorus removal is a project requirement the use of chemical precipitation with alum, ferric chloride, or other chemicals in a separate treatment step is suggested.

TABLE 5.11 Rate Constants for Estimating Nitrogen Removal with Eq. 5.1 in a Duckweed System[20]

Temperature and plant density	k, days^{-1}
Summer months	
Mean temperature 27°C ± 1°C	
Plant density, kg/ha (dry wt)	
Lemna minor	
73	0.074
131	0.011
Winter months	
Mean temperature 14°C ± 4°C	
Plant density, kg/ha (dry wt)	
Lemna minor	
40	0.028
67	0.012

Metals removal. Plant uptake of metals plays a lesser role in duckweed systems than described previously for hyacinths. The major removal mechanisms are chemical precipitation and ultimately incorporation in the benthic sludges.

Design considerations. The use of duckweeds for wastewater treatment is not as well developed as hyacinth systems and experience to date has been limited to laboratory and pilot scale research and field demonstrations. This experience suggests that the major function of the duckweed plants on lagoons of conventional depth is to provide a surface cover on the pond, rather than contributing directly to removal of pollutants.

The design of a duckweed pond system should, at this stage of development, follow the conventional design procedures for facultative ponds as presented in Chap. 4. Effluent from a duckweed covered system should exceed performance expectations for BOD, SS, and nitrogen removal as compared to a conventional pond system with an open water surface. The effluent from such a system is likely to be anaerobic and post aeration of some type may be necessary. The duckweed pond at Cedar Lake uses turbulent flow during a 0.9-m (3-ft) drop to aerate the final effluent.[31]

Wolverton[31] has proposed the use of a 3-m (10-ft) deep anaerobic cell preceding either hyacinth or duckweed covered basins. Odor control in the anaerobic cell is provided by a surface mat of duckweed plants 1 to 2 cm (0.4 to 0.8 in) thick.

Since the duckweed plants do not play a major role in direct pollutant

removal the use of inlet diffusers for initial wastewater distribution is not critical, as it was for hyacinth systems. Nor is the maintenance of an aerobic zone for mosquito control a factor since the mosquito larvae will not be able to penetrate a fully developed duckweed mat and therefore are not a problem. An effluent manifold is desirable to ensure utilization of the entire basin width for treatment. A screen or other baffling system is essential at the outlet of the basin to prevent loss of the small floating plants with the effluent. The basin configurations suggested for duckweed ponds are $L:W = 15:1$ to ensure plug flow conditions.

Pond systems in colder climates could be designed for the seasonal use of duckweed to significantly improve performance during the normal algal growth season. The pond cells could be seeded with duckweed soon after all ice had melted, and their rapid growth should ensure high quality effluent for the balance of the summer. The mat of floating plants on these systems should be harvested prior to the onset of freezing weather.

Operation and maintenance. The major operational concerns with duckweed basins are essentially the same as for the facultative ponds described in Chap. 4. Maintenance and harvest of the vegetation, control of odors and mosquitos, and sludge removal and disposal/utilization require some special concern.

The potential for excessive evapotranspiration losses from duckweed basins is not as significant as the losses from hyacinths. This is due to the very small size of the individual plants and to the thick surface mat that can develop.

Mosquito and odor control. As long as a thick surface mat is maintained on the duckweed basins, mosquitos should not be a problem. The mosquito larvae cannot survive in the anaerobic water beneath the surface cover and cannot penetrate a thick mat to obtain oxygen. To ensure rapid regrowth and maintenance of odor control not more than 20 percent of a basin should be harvested at any one time during the plant's growing season.

Effluent odor control may be a concern because the water in the basin is likely to be anaerobic at all times. Post aeration may be necessary in some situations. Odors may also be a concern at seasonal duckweed systems in colder climates. These basins may experience a spring and fall "overturn" due to temperature induced density differences in the water column. The resuspension of benthic material during the overturn period can result in objectionable odors. The problem is not unique to duckweed basins but can occur with any type of unaerated pond in colder climates. The typical solution is to locate these ponds at least 0.4 km (0.25 mi) from any habitation.

Vegetation management. Frequent plant harvests are not usually necessary since the major function of the duckweed plant is to provide a cover on the water surface. Harvest schedules and rates have not yet been developed from the limited experience with duckweed systems. It is necessary to have an effective surface mat of plants but it would also seem desirable to conduct a regular partial harvest to encourage semivigorous growth and to remove dead and decaying plants. Harvesting a broad area is not recommended since the remaining plants will be subjected to wind-induced drift resulting in their lateral compaction and further loss of surface cover. A reasonable value might be 20 percent or less of the basin area at any one time. Harvesting procedures typically utilize some type of floating device such as booms or pusher boats to bring the plants to the bank of the treatment cell and then they are removed using a method similar to the one described for hyacinths. In small basins this final removal can be a manual operation due to the small size of the individual plants. At several operational systems in Minnesota a patented floating plastic grid contains the duckweed plants in hexagon shaped cells and the floating harvester rides over the top of the cells to collect the plants.

Sludge removal. Assuming that regular harvesting is practiced, the benthic sludge in these duckweed basins should be similar to sludges in conventional facultative treatment ponds; the cleaning procedures and frequency will also be similar. Chapter 4 and Refs. 18 and 29 provide guidance on sludge removal from pond systems.

Utilization/disposal of harvested plants. The harvested plants can be used directly in the wet state as animal feed if transportation requirements are minimal. If significant off-site transport is necessary then on-site air drying is recommended. Drying times and procedures should be similar to those described in the previous section on hyacinths. Composting of the harvested duckweed plants should also be feasible.

5.2 Submerged Plants

The use of submerged aquatic macrophytes for treatment of wastewater has been tested in the laboratory and greenhouse and in a pilot scale field study in Michigan.[17] Table 5.12 provides information on some of the submerged freshwater plants that have been studied or considered for use in wastewater treatment.

The desirable water temperature for these plants ranges from 10 to 25°C (50 to 77°F), with growing being inhibited at temperatures above

TABLE 5.12 Submerged Aquatic Plants with Potential for Wastewater Treatment

Common name, *scientific name*	Distribution	Characteristics
Pondweed, *Potamogeton* sp. *P. amplifolius* is most studied type.	Worldwide	Has both floating and submerged leaves, reproduces from rhizomes growing in sediments.
Water milfoil, *Myriophyllum heterophyllum*	Worldwide	Highly branched stem up to 3 m long, vegetative reproduction.
Water weed, *Elodea* sp. *E. canadensis* is most studied type	Cooler parts of North and South America	Irregular branching stem, vegetative reproduction.
Coontail, *Ceratophyllum demersum*	Throughout U.S.	Rootless, branched stem, pinnate leaves, vegetative reproduction.
Fanwort, *Cabomba caroliniana*	Tropical and temperate U.S.	Highly branched from the base, whorled leaves, vegetative reproduction.

35°C (95°F). Turbidity of the water must not be high enough to prevent light transmission to the plants to support their photosynthetic activity and an aerobic environment is also necessary.

Performance expectations

The environmental requirements discussed previously would suggest that submerged plants might be best suited for final nutrient removal from previously treated and clarified wastewater, but there have been small scale greenhouse tests using primary effluent in aerated containers.[9] The units with *Elodea nuttalli* did demonstrate significant removal of BOD, phosphorus, and nitrogen, but the performance was just slightly better than the control units that contained no plants. The other plant species that were tested (*Myriophyllum heterophyllum, Ceratophyllum demersum*) were rapidly fouled with filamentous algae which in turn reduced productivity and system performance. *Elodea* was also a component in the pilot scale pond systems tested in Michigan.[17] Very significant nitrogen and phosphorus removals (nitrate from 15 mg/L to 0.01 mg/L and phosphorus from 4 mg/L to 0.03 mg/L) were achieved, but were ascribed to factors other than plant uptake.

ANNEX D

INITIAL ENVIRONMENTAL EXAMINATION

ANNEX D: INITIAL ENVIRONMENTAL EXAMINATION

D.1 Introduction

This Initial Environmental Examination (IEE) (pre-feasibility level Environmental Impact Assessment or EIA) follows the steps specified in the *Bangladesh Flood Action Plan Guidelines for Environmental Impact Assessment* (ISPAN, 1992). These steps are illustrated in Figure 2 of ISPAN (1992).

Much of the information required for the IEE/EIA appears in the main body of the study. The section and chapter references given below cite this information.

D.2 Proposed Project

D.2.1 Project Design and Description (Step 1)

As described in Chapter 3, Project Overview, and Chapter 6, Detailed Descriptino of Work Packages.

D.2.2 Environmental Baseline Description (Step 2)

As described in Section 2.2; in the *Northeast Regional Water Management Plan*; the *Wetland Resources Specialist Study*; and in the other NERP reports (see list, pp. ii and iii).

D.2.3 Scoping (Step 3)

Technical:

Literature review: As described in the *Wetland Resources Specialist Study*, Chapter 3.

Local community: As described in the *Wetland Resources Specialist Study*, [new section to be prepared based on 1993/4 winter season field work].

D.2.4 Bounding (Step 4)

Physical:

Project area: Northeast Region.
Impacted area: Northeast Region, plus areas linked to it through processes such as migration, and downstream areas affected by surface water quality contamination/management occurring within the region. Global biodiversity impacts in terms of measures intended to benefit globally threatened species.

Temporal:

Project duration: As described in Section 3.7, Phasing.

Cumulative impacts:

With other development projects and processes: Intent of project is to mitigate the adverse biodiversity and surface water quality impacts of continuing human utilization of wetland and upland landscapes.

D.2.5 Field Investigations (Step 5)

Field investigations are described in the *Wetland Resources Study*, Chapter 2, Study Overview.

D.2.6 Impact Assessment (Step 6)

Biodiversity component: Given the nature of this project, no adverse impacts can be identified as yet. As site management plans and species recovery and reintroduction plans are developed, they should be subjected to systematic review to identify and properly manage any adverse impacts.

Surface water quality management: Adverse impacts (e.g. displacement of current land use) could occur at sites where pollution abatement facilities are to be constructed. As work proceeds, these should be dealt with.

Institutional development component: No adverse impacts.

D.2.7 Quantify and Value Impacts (Step 7)

Adverse impacts will become quantifiable as specific plans for intervention are developed. All such impacts are expected to be localized, minor, and manageable.

D.2.8 Environmental Management Plan (Step 8)

Mitigation and enhancement. Measures should be incorporated as/when needed.

Compensation. Measures should be incorporated as/when needed.

Monitoring. Monitoring could be carried out through NEMREC, assuming NEMREC becomes operational within the required timeframe.

People's participation. People's participation in environmental management of any adverse effects of project activities should build upon ongoing project participation mechanisms.

Disaster management (contingency planning). Not relevant.

EMP institutionalization. Local Conservation Centres or NEMREC would be the obvious choice.

Residual impact description. This should be generated as/when appropriate, as part of management/recovery/reintroduction plans.

Reporting and accountability framework. Should be established through local Conservation Centres or NEMREC.

Budget estimates. Costs should be estimated as part of budgets for managment/recovery/reintroduction plans.