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Flood Action Plan

North West Regional Study (FAP-2)

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CHAPTER 1

CONCLUSIONS

This Chapter summarises the main points of relevance to the development of FCD interventions, and suggests a number of mitigation and enhancement options which may be applied.

1.1 Ecological Implications of Water Quality Variables Measured in this Study

1.1.1 Toxicology

No significant levels of any common toxins were detected in this Study, but they are reported to be locally significant near industrial units in Gaibandha and Bogra. Similarly, in the field and DoE archive studies carried out for the Jamuna Bridge Impact Assessment (GHK/MRM, 1991), water quality data for the Buriganga River downstream of the worst sources of industrial effluent from the Dhaka industrial areas did not demonstrate any significant toxic threat to fish even at the end of the dry season when conditions are at their worst.

The water available for exploitation in the Region is generally of good chemical quality, although its low hardness provides only weak buffering capacity. The calcium in hard water is a good general antagonist of many toxic pollutants when they are dissolved in water, and its low concentration in Jamuna water means that any toxic materials dissolved in the water will exert detectable effects at fairly low concentrations. Many fish larvae and fry are particularly sensitive to toxins, and water quality standards aimed at protecting fish and other aquatic life should reflect the low hardness of the water supplies.

1.1.2 Bacterial Contamination

The bacterial quality of many surface water supplies is unsatisfactory, and is a major cause of diarrhoeal disease outbreaks. Without adequate sanitation development, this situation cannot be expected to improve. The lack of appreciation of the risks of contaminated water to human health requires attention.

The chemical standards set for drinking water are in some cases irrelevant - for example the minimum value set for dissolved oxygen (6mg/l) would preclude every tubewell source tested in this Study, despite their being generally the best quality water available in the Region. Groundwater, particularly that from deep tubewells, represents the safest source of supply for human consumption. Shallow tubewells, especially hand-operated units, are often constructed with inadequate sealing around the wellhead, and this permits contamination of the adjacent zone of the aquifer by downward seepage of contaminated water from the surface.

1.1.3 Iodine Deficiency Syndrome

The low level of iodine in all water sources is responsible for the widespread incidence of iodine deficiency syndrome and the high incidence of cretinism in some areas. However, the uneven intensity of the problem suggests that there may be some plant resource which is capable of accumulating iodine, and some effort should be made to investigate this in view of the administrative problems of distributing iodised salt to the more isolated parts of the Region.

1.2. Water Quality and Aquatic Productivity

1.2.1 Turbidity as a Major Environmental Constraint

The most significant factor controlling primary aquatic productivity is light penetration into the water. The heavy silt loads of the principal rivers throughout the year, and of the more mobile flood waters during the flood season, severely limit energy capture in the aquatic habitats, and most of the energy available to aquatic organisms is derived from energy captured by terrestrial plant photosynthesis during the dry season.

1.2.2 Oxygen Concentrations

In the surface waters, oxygen concentrations are rarely low enough to present any threat to fish and other aquatic organisms. In standing waters phytoplankton provide a biological source of oxygen during the dry season, but this process fails in all except the most sheltered waters during the wet season. However, the high levels of dissolved oxygen in the rivers, even when they are carrying most silt and therefore incapable of supporting phytoplankton, indicate that turbulent flow and surface absorption are sufficient to ensure full oxygen saturation at all times.

1.2.3 Nutrient Availability and Phytoplankton Growth

Plant nutrient levels in the surface waters are adequate for phytoplankton growth, and silica levels are high enough to permit strong growths of the Bacillariophyceae (Diatoms) which compete with the Cyanophyceae ('Blue-green algae') more effectively under these conditions.

However, in standing waters phytoplankton nutrients are rapidly absorbed, and Cyanophyceae frequently become dominant. It is possible that some fish mortalities reported during the dry season may in fact be due to phytotoxin produced occasionally by the Cyanophyceae, rather than to unspecified pollution by industrial and agrochemicals as is widely alleged.

FCD interventions are unlikely to have any significant effect on surface water oxygenation, since reducing current flows permits the development of phytoplankton, which form an alternative source of supply for aquatic organisms.

1.3 Soil Biology

1.3.1 Energy Efficiency of Residue Recycling

There is a cyclic alternation in biochemical oxidation in the soil, as water saturation during the flood season reduces oxygen availability. During the dry season, organic residues are recycled by the energy-efficient process of aerobic oxidation, whereas when soils are flooded the process is carried out by the very much less efficient anaerobic glycolysis.

1.3.1 Nitrogen Fixation

The activities of nitrogen fixation by the Rhizobium - legume symbiosis are suspended during the floods, although the poor representation of the Leguminous on the floodlands means that this loss is probably not very significant.

1.3.2 Impacts of FCD on Highland Resource Availability

Increased soil water levels in the highlands may inhibit the ability of many trees to absorb nutrients, a process promoted by the fungae-tree association. FCD interventions which reduce the water-table in highland areas therefore have the potential to improve the nutrition of trees, which provide the most important ranges of natural resources for rural people.

1.3.3 Nitrogen Fixation on the Floodlands During the Flood Season

The fixation of atmospheric nitrogen by terrestrial plants is replaced by the same process carried out by submerged Cyanophyceae in the plankton and by floating commensal (usually Pteridophyte - ferns) during the floods. The contribution from such sources is probably of the order of 35-50 kg/ha of nitrogen, which is incorporated into the soil as the flood waters recede. This source is particularly valuable, since it is a 'slow release' fertiliser, and therefore equivalent to several times its nominal weight of artificial chemical fertilisers which are subject to rapid leaching. However, the full potential for using these biological nitrogen sources is substantially higher than the current agricultural practices allow.

1.3.4 The Role of Fish in Agriculture

When the land is flooded, the fish provide an alternative high efficiency energy recovery and recycling pathway, since they are able to employ oxidative processes because they extract oxygen from the water for their metabolism.

The wastes ejected by the fish during their growth on the floodlands are recycled by the phytoplankton, including the Cyanophyceae, and are therefore made available to the terrestrial plants once the flood waters recede and the algae die and become incorporated into the soil. So the floodland energetics are maximised in efficiency by the semi-annual rotation of alternative chemical processes.

1.3.5 FCD Interventions and Soil Biology

FCD interventions have the potential to affect soil biology because they alter the balance between the two groups of processes which alternate through the annual inundation cycle. The present semi-natural system relies to a considerable degree on the aquatic components, and FCD interventions which cause an increase in the length of time that the soils remain unsaturated each year will certainly cause a reduction in nitrogen fixation. This represents a major cost to the agricultural sector, since this nitrogen is another of the 'free goods' of the floodplain which will need to be replaced by traded goods if the natural cycle is disturbed.

1.3.6 The Need for 'Nitrogen Harvesting' by the Agricultural Sector-Enhancement of the Efficiency of Agriculture

Only the adoption of active policies of nitrogen harvesting by the Leguminous as an integral part of the agricultural system, in contrast to the present low level of dry season nitrogen fixation, will redress this loss with minimal cost. Indeed, the adoption of such nitrogen harvesting technology as is already available elsewhere would be capable of producing a substantial improvement in the yields

of a number of existing crops-Subba Row and others have quoted increases in rice yields of up to 50% from the adoption of Azolla-rice culture techniques. If these techniques are adopted in conjunction with FCD interventions, then a positive benefit to soil productivity may be available.

1.4. The Major Terrestrial Habitats.

1.4.1 Crop Lands

The croplands are generally regarded as the most important areas in Bangladesh, and it is correct to attribute the highest economic values to them. From an ecological viewpoint, however, they are almost barren, with extremely low species diversity and abundance values. The field margins provide facilities for a surprisingly wide range of plants and animals, and the small field sizes undoubtedly plays an important part in the maintenance of some diversity across the agricultural lands as a whole. The adoption of a more enlightened approach to intercropping, especially with nitrogen fixing species, would greatly improve diversity, with a number of benefits.

Intercropping with these species does not necessarily reduce crop yields, because over a number of years both the soil nitrogen reserve and the soil structure improve. In addition, the intercrop species can be used as high food value fodders for livestock, a factor of considerable importance in maintaining draft power capacity on the farms.

The increase in diversity also promotes pest management, since a more diverse field system will support more species which are able to predate crop pests.

1.4.2 The Highland Habitats as Centres of Diversity

The vast majority of the natural resources of the Region are centred on the highlands. Floral species diversity is far higher in these habitats, and it is notable that the most common forms of dominant species have a large number of uses. The importance of these resources almost certainly exceeds in value even the fish resources of the floodlands for poor people, since they provide shelter, food, materials for earning money from craft work, and free medicines as well.

The floral diversity promotes a comparatively high animal diversity, and it is noticeable that a very large number of the birds which are common in the highland homestead areas feed principally on insects. The highland homesteads therefore represent a major refuge for crop pest control species. The lack of investigation of insect species precludes speculation of the role of these habitats in providing refuges for those insects which also help to control insect crop pest species.

1.4.3 FCD Interventions and the Diversity of Highlands

FCD interventions may potentially encourage the preservation of the floral and animal diversity in the highlands by reducing high water-tables in the flood season. This will enhance the growth of the trees which form the dominant group in the highland habitats, and so improve the resource availability of those species which rely on them.

1.4.4 Embankments

The embankments are floodland habitats which have some of the characteristics of highland. It is therefore not surprising that they have a diverse biological community. They act as refuges for people and animals alike during floods, and this may result in some conflict for space and resources which frequently is to the detriment to some human individuals who may fall victim to venomous snakes.

However, the role of the snakes in controlling the mammalian commensals of man, such as the mice and bandicoots, should not be overlooked. Since some small mammals can act as vectors for serious human diseases, snakes should be seen as playing a positive role in the regulation of public health hazards, despite the manifest hazard associated with a few species. (It is worth emphasising that the majority of snakes recorded in this Study were not venomous).

The embankments serve as important linear habitats and are major dispersal corridors for many species, some of which may be reservoirs of infection of diseases which affect humans. They are also important as dispersal routes for the agents of some contagious human and animal diseases. They provide shelter - often the only shelter - amongst the open and generally treeless fields of the floodland for the wild birds which feed on insects which may at times become crop pests.

1.4.5 Beels

The importance of the beels does not lie in their conventional role as wetland reserves for wildfowl, but as dry-season refuges for the floodland fish. The preservation of the fish stocks, which should be a matter of international concern, demands that the present network of beels and river channels should be maintained and the fish sheltering in them protected by sound and effective management policies, to ensure that their access to their essential energy source, the floodland, is continued. In FCD terms, this means that compartmentalisation centred on the major beel complexes but allowing some access to the river channels as well, is the correct approach to the management of the fish stocks of the Region.

1.4.6 Fish Fry Distribution

The importance of the timing of access by spawning fish and planktonic fry to the floodplain has already been described in relation to the longitudinal fish migrants - mainly the major carps (Cross, 1992), and FCD planning for providing such access is already beginning to appear. However, it is important to realise that the peaks of abundance of fry in the river waters may only extend for two or at most three days at a time. Access to a large area of the floodland by fry in such a short period can only be achieved by allowing large volumes of water to move across the floodlands in this short period. Structures which attempt to concentrate fry in small volumes of water will almost certainly result in increased predation by larger fish, as well as intensification of the already excessive fry harvesting by man.

In addition to these problems, the post-larval fry need to gain access to the feeding grounds within a very short time of using up their yolk supply, since there is no food supply available to them in the rivers. The only source of the essential high-protein foods (zooplankton) is the more sheltered beels. Any delay in their gaining access to these waters will cause substantial mortalities, an eventuality to be particularly avoided since fry numbers are already in very serious decline in the Region, and indeed over almost all the country. FCD structures designed for fry access facilities therefore must not delay access to the floodland, since the fish are at a very critical time in their life cycle, and even apparently short delays will be fatal to many.

1.4.7 The Char Lands

The charlands are the most ecologically diverse of the floodland and lowland habitats, but show the lowest resource potential for human occupancy and colonisation. There is a distinct pioneer plant assembly, the dominant members of which are generally either noxious to grazing animals or extremely small and compact to reduce drag during the floods. Despite the general attraction of the lowland river channels and charlands for water-living birds, the Bangladesh charlands are very sparsely inhabited by wild birds of all kinds, and cannot be regarded as major wild bird or wildfowl habitats. There are therefore no significant conservation issues which are of specific relevance to FCD interventions.

1.5. Energetics and the Ecology of the Floodland Fish Stocks

In the Jamuna and Teesta Rivers, young fish in their first year after hatching (year-class 0+) fish play an important role in the transfer of chemical energy contained in organic residues on the floodplain at the end of one dry season to the aquatic environments at the start of the next. The anomalously high fish species diversity is a result of niche specialisation for exploiting terrestrial energy sources, rather than very small niche hypervolumes in the dry-season river ecosystem.

1.6. The Use of Hydraulic Modelling in Floodland Ecology

The MIKE11 hydraulic model is an indispensable tool in predicting the impacts of FCD interventions on many ecological processes and relationships on the floodplain. Modelling of the predicted impacts of flood control interventions using the General Model has indicated that synchronicity between over-bank flooding and the peak of fish fry recruitment potential is an essential relationship in maintaining the integrity of the energetics of the floodplain ecosystem. Its use in associated fields, such as public health and resource availability should be developed for future FCD and associated developments throughout the inundation-prone areas of the country.

CHAPTER 2

BACKGROUND

2.1 Introduction

This Chapter provides a broad general background to the Ecological Survey, and a framework for approaching the analysis of the ecological data.

2.1.1 The Appreciation of Ecological Processes in Bangladesh

Whilst there are a considerable number of ecological studies being undertaken in Bangladesh, almost all are devoted to investigations of the details of specific processes relevant to branches of pure and applied botany and zoology. In the North West Region as a whole, ecological processes appear not to have been studied even at relatively superficial levels, and many papers in Journals such as that produced by the University of Rajshahi Zoological Society are generally of a highly specialised nature.

During 1991, studies were carried out by GHK/MRM and Hunting Technical Services on the possible environmental impacts of constructing the Jamuna Bridge. This study revealed that there is a fundamental conflict of interests between the development of agriculture in Bangladesh and the management of the floodplain fisheries. Subsequent development of the methodology initiated in that study indicates an urgent need to overcome the current dichotomy between terrestrial and aquatic ecology, and to develop a more integrated conceptual model to describe the relationships between the floodplain aquatic and terrestrial habitats.

Within the Flood Action Plan itself, a number of studies are addressing the possible impacts of flood control interventions on the agricultural and fisheries sectors, and FAP 17 is specifically devoted to an examination of fish dynamics and related ecology. However, at the present time it is still true to state that no wide-ranging ecological study of the ecology of the interior of Bangladesh is available which would allow an integrated appraisal to be made of the full range of ecological impacts which may arise from interventions in the future.

Many FAP studies have already commented on the lack of reliable and comprehensive ecological baseline information, and a number are beginning to address this constraint in limited areas and specific environmental fields. A large part of such efforts is rightly devoted to looking at the impacts of changes in the environment on the people who will be most affected by them - mostly poor people with minimal or no land resources.

But it is still clear that many of the present paradigms which educated specialists and consultants use to describe the rural agricultural sector are unsatisfactory. The psychological motivation and rationale of survival strategies commonly adopted by people exposed to serious environmental risks are poorly or even completely unknown. So practices such as the deliberate and extremely laborious raising of the levels of small fields by human toil remain unexplained - it is quite obvious that such work is regarded as a worthwhile investment by agricultural peoples, yet we do not understand the motivation or economics of such practices.

The same deficiency is evident in many environmental studies. For example, it has been repeatedly claimed that the poorly-controlled use of pesticides is a major problem in Bangladesh, and that together with fertilisers they represent a substantial environmental threat, especially to the groundwaters from which so many people derive their drinking water supplies. Yet there are no data on which such claims can be either supported or rejected.

Similarly, it is widely supposed that reduced yields of floodplain fish after intervention can be calculated by adjusting the previous yields downwards in proportion to the area of floodplain which will no longer flood. Such assumptions are without foundation, since they equate production directly with the extent of intervention, and demonstrate no regard to, or understanding of, the basic processes by which fish arrive on the floodplain or achieve their often spectacular growth.

2.2 Limitations on Ecological Research in the FAP2 Study

In ecological terms, the floodplain in the North West Region is almost totally dominated by human activities, and for all practical purposes there is little 'natural ecology' left. The scarcity of bird life makes an immediate impression on field excursions into the rural areas of the Region, and in many areas only tiny relict patches of uncultivated wild land remain, often visible as conspicuous and incongruous features in an otherwise uniform landscape. These now form refuges for individuals of species which were once far more widely distributed and undoubtedly more common, in the days before man converted the former floodplain forests and grasslands to ever-intensifying agriculture.

In this study, therefore, methodologies have been adopted which provide a first general description of the broad ecological relationships between wildlife and man. Since human population pressures are so heavy and the region is subject periodically to substantial environmental threats, the study is directed at identifying the principal links between man, wildlife and the major types of habitat. The methodologies adopted resemble those used in Rapid Rural Appraisal (RRA), relying on obtaining a wide range of ecological data on a 'snapshot' basis. Following changes in processes and populations over an extended period of time has not been possible - instead, large amounts of field data have been assembled and screened to pick out patterns and general relationships. Inevitably, many subtle relationships will be missed, and in the final analysis the process relies heavily on the experience of the team involved.

2.3 Functional Ecology

A major concern of this study has been the elucidation of the functional ecology of the floodplain system. Functional ecology deals with the underlying processes which link all components of the living landscape - plants, terrestrial animals of all kinds including man, and the inhabitants of the aquatic habitats. Past studies have been strongly compartmentalised, with most emphasis being placed on agriculture, rather less on fisheries, and remarkably little on human ecology. Indeed, in many cases, all three sectors have been ignored more or less totally, in the rigid application of engineering 'solutions' for which the real problems have rarely been clearly defined.

Yet all three sectors are intimately linked by one fundamental relationship, that of energy transfer. Energetics is the study of the ways in which energy is distributed through an ecosystem -indeed, it actually defines the extent of an ecosystem. Conventional environmental approaches would recognise a 'terrestrial ecosystem' and an'aquatic ecosystem', and examine them separately. But the Bangladesh floodplain is (or at least originally was) one single ecosystem, in which energy transfer processes between the land and the water were of extreme importance to both.

Whilst the energetic relationships between the terrestrial habitats and the river fish stocks have been recently described by Cross (1992), the continuing dependence of the terrestrial habitats on processes which are greatly influenced by the annual inundation cycle is still poorly recognised. In the lower reaches of the river system this relationship is still appreciated, through the obvious dependence of many estuarine and marine species on the presence of the mangrove forests of the coastal fringe. Yet the corresponding relationship between the aquatic and terrestrial environment further inland has become blurred, and is largely assumed to be of little or no importance.

2.4 Structural Ecology and the Anthropocentric Approach

Once the functional ecology of the region has been clarified, the structural ecology can be defined. Structural ecology deals with the actual components of the ecosystem - the soils, water, animals, plants and humans which make up the visible sector of the system. The present study aims to identify the major groups of components which make up the more important sub-units of the floodplain ecosystem, and to improve our understanding of the linkages between resources and people.

This is not meant to indicate that traditional conservation interests are treated as secondary in this study. Indeed, the energetics approach provides a peculiarly distinct insight into the practical role of biodiversity in the floodplain ecosystem, and of the real value of genetic diversity to human interests. The real value of species conservation, as a process which will facilitate the maintenance of the unstable energetic state of the environment, is clearly of great significance.

It is fashionable to decry the application of ecological principles to the specific interests of mankind, and in some environments which are largely unaffected by human interventions this may be justified. However, Bangladesh is not such an environment, and it has to be acknowledged that human interests are now of overwhelming importance, since without urgent attention to basic production issues the rapidly increasing population will quickly outstrip the capacity of the environment to support them - in ecological terms, the carrying capacity of the floodplain will be exceeded and the probability of a subsequent increase in morbidity and mortality rates will become an inevitable consequence.

The reason for the anthropocentric emphasis should be easily apparent. Whilst there are of course large numbers of poor people in the towns and cities, few of these are directly reliant on immediate and continual access to natural resources. But in the villages, a very large proportion of people are poor, and they rely substantially on access to 'commons' or common property resources - essentially free goods, such as those which are provided by the capture fisheries and the wild plants of the homesteads, road sides and field margins. If access to commons is reduced, as when these resources are damaged unnecessarily by poorly planned or ill-considered interventions, then the health and welfare of the weakest and most disenfranchised sector of the population will inevitably be put at risk.

The value of such common property resources is almost always under-estimated in conventional economic analyses, assuming that they can be replaced at discounted international traded rates. Yet these bear no relationship to the means of the poor. The value of free goods to people who have to develop efficient strategies in order to survive at times of scarcity or extreme danger is notoriously difficult to quantify. In humanitarian terms, no valid financial price can be placed on resources the absence of which may spell the difference between life or death in emergency situations.

Indeed, the ethical dimensions of ecology, and their relevance to planning for the public good soon become apparent in such difficult areas. The linkages between ecology (in its more generally used context) and that branch of human ecology known as sociology are sharp reminders that man is indeed an integral component of the ecosystems in which he lives. These choices cannot be made by ecologists and environmental analysts alone, for they are ultimately community decisions and choices, requiring full and open consultation with those most likely to be affected by their implications.

Political decisions have to be made regarding the criteria to be used in selecting options which may dictate whether or not the risks to particular groups will increase beyond tolerable limits. Unfortunately, no guidelines exist as to where such tolerable limits might lie, and all too frequently, such decisions are avoided, because the responsibility for the consequences of serious errors is great. Where such difficult choices exist and can be identified in this study, they will be stated clearly and unambiguously, and guidance provided where possible. But where there are fundamental conflicts of interests which cannot be solved by the bio-physical sciences, political judgement and decision must ultimately provide the essential guidelines for linking environmental factors and the planning of the future management of natural resources

2.5 Structural Ecology of the Jamuna Floodplain

2.5.1 Primary flood patterns

The floodplain of the North West Region is dominated by the Teesta and Jamuna Rivers, but much flooding during the wet season is also caused by heavy rainfall and impeded run-off. The Region is therefore exposed to two quite distinct sets of environmental condition each year. During the dry season, which extends approximately from November to May, the land dries out, and water bodies such as the beels and non-permanent rivers slowly lose water by evaporation and seepage; they are also subject to deliberate abstraction by man for crop irrigation. Consequently, almost all floodplain aquatic habitats gradually reduce in area, and by the end of the dry season many are completely dry. In many areas of the Region the lack of water may be sufficient to cause damage to crops, so in recent years the use of tubewells to abstract groundwater to irrigate crops has reduced the areas of parched soils. With these changes in agricultural practices, new habitats have been created.

In May the rivers begin to rise as snowmelt in the catchment swells the discharges, and by June over-bank spillage develops along substantial stretches of the river channels, resulting in widespread inundation of the floodplain. At around the same time the monsoon season starts, and much of the land is subjected to sheet flows, as water attempts to leave the Region through the main drainage channels of the Ghagot, Atrai and Karatoya Rivers. The patterns of spills and runoff flows vary considerably each year, depending on the location and size of natural breaches in the banks of the main rivers (or of the flood control banks erected to try to reduce over-bank spillages), and on the timing and severity of the monsoon rains.

However, it is important to bear in mind that over-bank flows do not occur along the whole length of every river bank. Before the present programme of flood protection embankments was instigated, there were certainly long stretches of banks over which spillage from the main river channels was able to inundate large areas of the floodplain. This spillage combined with rainfall runoff to produce characteristic drainage pathways which eroded channels in the soft poorly-cohesive floodplain soils. This resulted in the formation of a succession of meander channels and ox-bow lakes, the water supply to which varied from annual flood flows from the main rivers to surface runoff derived purely from rainfall. In addition, naturally low-lying areas with restricted drainage formed permanent or semi-permanent pools (beels) which often have a substantial history of isolated ecological development.

This situation has been modified in recent years with the increasing construction of embankments designed to reduce flood risks and to enlarge those areas of the floodplain which can be used for modern agriculture. Consequently, some habitats have been altered, either because the flooding regime has changed permanently or because they are no longer subjected to a regular, predictable cycle of change every year.

2.5.2 Secondary Flood Patterns

For a substantial part of the flood season, surface drainage from the internal drainage system of the North West Region (through the Ghaghot, Atrai and Karatoya Rivers) is impeded due to the relatively high levels of water in the Jamuna River. This is supplemented by a pronounced backwater effect at the mouth of the Atrai/Karatoya system, related both to the high level of the Jamuna itself and to high water levels in the lower channel of the combined Jamuna, Padma and Meghna Rivers. As a result, although water continues to drain from the Region through the Atrai system, it does so more slowly than the general topography suggests, and the lower Atrai Basin is peculiarly susceptible to extended periods of deep flooding during parts of the wet season.

2.6 Major Macro-habitats

The Region contains three major macro-habitats. Of these, the floodplain proper and the river channels form the floodland and lowland respectively. In addition there is a distinct zone of highland which is free of significant flooding, although some may be inundated for short periods during exceptionally high floods. Many areas of such highland are isolated within the floodplain itself, but there are also extensive areas of permanent highland along the western side of the Region which are outside the zone of direct physical influence of the Flood Action Plan.

In addition, there are a number of other less extensive areas which have their own environmental peculiarities. Of these, the lowland chars in the river channels are of significance to human ecology, since they are exposed to some of the more extreme variations in environmental conditions, and the welfare of the many people who attempt to maintain a precarious living on them is often a matter of considerable hazard. The chars are little more than low sandbanks in the channels of the major rivers. The Jamuna and Teesta themselves are braided rivers, in which the flow patterns are continually changing from year to year, and even more rapidly at many locations, to the extent that it is often impossible to identify particular chars over more than a few decades.

The chars are therefore temporary or semi-permanent land zones in which the normal ecological process of species colonisation and succession is either absent or interrupted, and the species which are able to gain a foothold are generally pioneer species which are adapted to such conditions.

In the southwest of the Region a tract of permanent highland exists which is never subjected to flooding. This is the Barind Tract, an area of clayey and relatively dry soils on which extensive forests once grew. The relative permanence and stability of the Barind Tract has resulted in well-developed primary succession communities, but these have been substantially depleted in recent times as human population pressures caused increasingly heavy exploitation of its resources and interference with its wildlife. This interesting and important area has not received the attention that it deserves in this study, due to restrictions of time and the more pressing need to characterise the ecology of those parts of the Region most likely to be affected by Flood Control projects in the immediate future. Similarly, the highland areas of the northwestern sector of the Region have also had to be excluded from this study.

The floodplain ecological zones are classified according to their distribution according to elevation above the river levels, and correspond only partly to the zones used in agricultural land type classification in Bangladesh. The three major zones are highland, floodland and lowlands. 'Highland' corresponds to the agricultural zone commonly referred to as highland. 'Floodland' corresponds to medium highland 1 and 2, lowland and very lowland, and includes the beels. 'Lowland' comprises zones not normally included in agricultural zonation, i.e. the river channels and banks. Because they are intimately associated with the river habitats, the charland banks and flat areas have been included in this zone. It is therefore important to bear in mind the differences between agricultural and ecological usage in the following text.

2.6.1 Highland Habitats

Terrestrial habitats of the floodplain are almost entirely regulated by their elevation in relation to flood peak levels in the present and recent past. The term highland refers to land which is not normally inundated even at peak flood levels, but except in the Barind Tract and parts of the northwest, this should not be thought of as land which is significantly above the general level of the floodplain. In fact, very few areas of land in the Region are more than a few metres above extreme peak flood level, and for up to six months every year many of the soils of even this 'highland' become saturated, as water-tables rise very close to the surface.

Because the human population pressure is intense, all highland areas have a high primary value as permanent agricultural land, but they also act as seasonal refuges for non-resident families during the annual flood season, as well as refuges for livestock and wildlife. Consequently, there are significant cyclic changes in the population densities of all forms of mobile terrestrial animals, as they move from the floodplain to highland refuges and then disperse back to the floodlands as the waters recede around November each year.

A wide range of habitats exist within the highland zone, and the principal ones (excluding urban areas) have been examined in the present study:

- Homestead areas. These are permanent settlements which are often deliberately managed by planting a variety of crops, fruit trees, timber trees and vegetables.

- Embankments. Flood control embankments provide essential refuges for people and wildlife during peak floods. Where villages have been destroyed by lateral encroachment of the river channels, displaced families often set up their homes on embankments.

- Single species woodland stands. These are generally old plantations which have been deliberately established by man, but may have become invaded subsequently by secondary species. No forestry plantations have been examined in the present study. Bamboo stands are a special variety of this habitat, since the plant is not a tree but a herb (actually a member of the Graminae - grass - family).

- We have tentatively identified a fifth type of highland habitat as 'refuge' areas, although the exact zone to which they belong is not always clear. These are very small isolated patches of land which appear never to have been cultivated, for reasons which are at present obscure. They are frequently found standing amongst rice fields in the floodlands around beels.

- Fishponds. Although these are strictly speaking aquatic habitats, true permanent fishponds are found only in highland areas, and are included within this group because they provide unusual environmental conditions around their margins.

2.6.2 Floodland Habitats

Flood lands are characterised by seasonal flooding. No distinction is made between flooding caused by over-bank spillage or river bank or embankment breaching and that due to surface runoff caused by rainfall. Indeed, in some areas such as the Lower Atrai Basin, any or all of these may be responsible for inundation in different years. The whole floodplain has been formed in relatively recent times, and the soils have been laid down as a succession of fluvial and inundation horizons, which are characterised by different particle sizes.

The fluvial deposits are generally porous sandy horizons, forming an intermeshing three dimensional network of aquifers. The soil horizons formed by inundation are generally finer grained silts and clays, which have been deposited either by low velocity river flows or by the erosion and transport of existing silty deposits by surface runoff across the relatively low gradient floodplain. The surface soils of those areas of the floodplain which have not recently been subjected to major overspills from the river channels are usually silty clays which are more suitable for agriculture, and they are intensively cultivated. The sandy outwash fans which form on the land side of major breaches are extremely difficult to cultivate, and are generally less disturbed than the silt soils:

(a) Floodland homesteads

- Not all homesteads are on highland. Some are actually situated on floodland, but have been artificially raised by excavating soil from an adjacent field and building a substantial mound which rises above the general flood level. Such homesteads are always associated with a nearby borrow pit, which serves as a multipurpose pond for washing, livestock watering and the irrigation of vegetable beds within the homestead area. They may also be used occasionally as temporary fish stewponds, and even for the supply of domestic water. Other homesteads are situated on land which is subject to inundation, and in these flooding is an annual fact of life unless they are protected by being inside a flood protection embankment.

- Floodland is very extensively used for cultivation of field crops, and a number of habitats have been described:

- Protected homestead areas. These are homesteads established on floodland inside a protective flood embankment. They are subjected to occasional rapid (sometimes disastrous) flooding if the integrity of the embankment is destroyed.

- Inundated homesteads. These are homesteads which are on floodland but are not protected by flood embankments. They are generally found beside river channels, and are subjected to occasional shallow but fast-flowing inundations during unusually high floods.

- Beel community villages. These are similar to the above group, but are generally subjected to much lower current velocities at critical times. They are often fishing communities.

- Wheat fields. Large areas of land are used for wheat, and are often irrigated for at least part of the dry season. They are subjected to intensive management, by weeding, but normally have a fairly dry surface. They may be used for other 'dry land' crops when not being used for wheat culture.

- Wheat field margins. These narrow linear habitats for an interconnecting network of refuges for plant and animal species which prefer the type of habitat provided by dry crop culture.

- Rice fields. The rice field habitat is extremely specialised, being virtually aquatic. It has its own specialised fauna and flora, which is often subjected to severe exposure to toxic chemicals.

- Rice field margins. These form a similar type of linear habitat to the wheat field margins, but are much wetter.

- Beels. These are permanent or semi-permanent aquatic habitats, generally isolated during the dry season. They may be subdivided into those which are flushed by flood waters annually and those which receive only rainfall runoff from the surrounding land. The former are subjected to external recruitment of both aquatic plant and animal species, whilst the latter can be regarded as isolated habitats in which species populations and community structure changes progressively over an extended period.

Almost all are now subjected to increasing rates of depletion of their water as they are more widely used as surface water storage areas convenient for agricultural irrigation around their margins. They are also subject to very intensive fishing pressures, but some are stocked artificially, often using exotic fish species.

2.6.3 Lowland Habitats

The lowland habitats are fluvial in nature. Within the river channels, both past and present, the deposition of relatively coarse-grained particles of sand has resulted in a mobile system of sandbanks, locally called chars, which represent the only source of new land for colonisation, for both humans and for plants and wildlife. The fluvial habitat is extremely capricious, with extreme changes in the depth and configuration of the river bed, even during the dry season. This is reflected by the constant erosion of the banks of the permanent river channels, and the downstream migration of chars over a period of years:

- Permanent river channels. The permanent river channels are characteristically almost barren. They carry a high silt load throughout the year, preventing the establishment of aquatic flora.

- Temporary river channels. Many of the rivers in the Region only flow for the wet season and a short period after. During the dry season the channel changes from a rapidly-flowing environment carrying a very high silt load to a series of shallow, stagnant pools in which the silt settles out, allowing light penetration and the growth of phytoplankton. During the dry season, environmental conditions in these pools approach those which develop in the flushed beels of the floodplain. In many cases, the channels of the temporary rivers are deliberately subdivided by cross-dams. These are made by people dwelling beside the channels, for the purposes of irrigation, stock washing and watering, and many other uses. They are therefore ecologically similar to the seasonally-flushed beels.

- River banks. These form narrow linear zones of unstable, and often temporary, habitats, and may be the only non-horizontal soil profiles on the floodplain apart from the artificial embankments used in flood control projects.

- Chars. The chars are unstable banks deposited in the river channels, and consist principally of loosely-packed sand grains. Gradual infiltration of smaller sized particles of silt and clay, followed and often assisted by the establishment of a cover of pioneer plant species, results in a gradual stabilisation, which may eventually permit human colonisation and the development of agriculture. Chars have been subdivided into four distinct habitat types:

    - o Char banks, close to the water and in constant risk of erosion.

    - o Char wet plains, consisting of large areas of dry sandy soils.

    - o Char wet plains, in which the watertable is close to or even slightly above the surface of the soil.

    - o Cultivated charlands on stabilised soils.

CHAPTER 3

METHODOLOGY

3.1 General

This Chapter provides information on the field collection methodology and on data recording, storage and processing.

3.1.1 Objective

The objective of the Ecological Survey is to provide baseline data on the terrestrial and aquatic habitats of the floodplain, and on the characteristics of ground and surface waters in the North West Region. In an area as large as the Region it is clearly not feasible to provide a detailed catalogue of sites, their fauna, flora and associated environmental variables. Instead, the Study has attempted to identify those habitats which comprise the largest part of the Region, and to provide definitive data which will provide a basic understanding of the relationships between then.

3.1.2 Orientation

Since the purpose of the Study is to provide environmental guidance in predicting the probable future ecological responses to FCD interventions, the methodology adopted is specifically aimed at revealing functional relationships rather than providing a detailed structural catalogue of Bangladeshi ecology. So particular emphasis has been placed on the distribution and usage of natural resources, and especially the exploitation of plants, upon which a very large proportion of the rural population depends to a considerable degree.

The Study has not dealt with fishery resources in any detail, since this resource is the subject of a separate Fishery Study. However, the ecology of both the terrestrial and the aquatic habitats are intimately bound together by the role of the floodplain fish stocks in energy transfer processes, and a consideration of this relationship has been included in the discussion of functional ecology.

3.1.3 Linkages

The health of the human population in the floodplain is intimately linked with environmental factors, such as the contamination of water or the seasonal concentration of poisonous snake populations on highland areas. Changes in both aquatic and terrestrial habitats occur on several temporal scales, daily, seasonally and cumulatively over several or even many years. The Study attempts to identify the time-scales of present processes and changes, and to show where these may change as a result of FCD interventions.

3.2 Survey Sites

Since the Survey is designed to provide guidance for the assessment of future FCD interventions, survey sites have been chosen which reflect this priority. The sites are all located within the Gaibandha Project Area, along those parts of the Teesta and Jamuna Rivers close to this area, in the Jamuna Right Embankment zone, or in the Atrai River Basin. A single river survey site in the Padma

River close to Rajshahi has also been studied, since the ecological character of the Padma River is believed to have changed since the completion of the Farakka Barrage. The locations of these survey points are shown in Figures 3.1 and 3.2, and a detailed list of sites provided in Table 3.1.

It should be appreciated that this Survey was not designed to provide a comprehensive guide of and catalogue to all the significant ecological sites in the Region. Its purpose was to categorise the major types of terrestrial and aquatic habitats within the potential areas of influence of FCD interventions, and describe their main ecological characteristics.

3.3 Water Quality Data

3.3.1 Methodology

A representative series of the major rivers and beels of the north-western region of Bangladesh were examined during the Study. Samples from surface water sources were collected at a depth of 0.5m from the surface using a hand operated pump.

Ground water samples were taken from randomly selected tubewells within the project area, generally the closest wells to the terrestrial and aquatic ecological sampling sites. Manually operated drinking water tubewells and machine operated shallow and deep tubewells usable for irrigation purposes were sampled after flushing the tubewell pipes long enough to ensure that the water samples obtained were representative of the water in the aquifer, and not of water which had been standing in the pipe for some time. The method therefore followed the guidelines issued by the World Health Organization (1987) for ground water sampling.

Transient variable such as temperature, pH and ammonia content of the water samples were measured on site using a Hach Water Analysis Kit. Samples for analysis off-site were kept in clean brown glass bottles with close-fitting ground glass stopper, kept in a cool box, and transported immediately for analysis at the Dept of Environment Laboratory at Bogra. The analyses were carried out according to standard analytical procedures (APHA-AWWA-WPCF, 1980; ASTM, 1987). The results of these analyses are presented in Table 4.1.

3.3.2 Collection of Field Data Related to Water Quality

In addition to taking water samples from each site, information was also sought on the use of agricultural fertilisers and biocides around or close to each sampling site, and also on the occurrence of fish diseases or mortalities (Tables 4.2, 4.3). Whilst these data are of limited value, and are in some cases at least, better dealt with by the Public Health Survey which is part of this Regional Study, they provide some background data on the prevalence of potential threats to water quality and the possible implications of contamination on human health in the immediate vicinity.

3.4 Terrestrial Ecology

3.4.1 Transect Surveys

Terrestrial ecology data were collected during transect walks, generally starting at a highland site and moving down towards a lowland site. At each type of habitat encountered on the transect, field notes and plant species collections were made, to record the presence and abundance of each plant and vertebrate species. Invertebrates were not recorded.

The method of assessing abundance was simple, intuitive and subjective. Those plants and animals which appeared to be dominant or extremely common were recorded as 'abundant'. Less common or dominant species were then allocated to one of four groups - common, frequent, occasional, and rare. Adequate resources for more detailed work were not available. Species lists and frequencies are presented in the Data Annex (Annex A), in Tables A 24 to A 88.

3.4.2 Rare or Absent Species

In addition to direct observation, local residents were asked about the occurrence of other species which were not recorded on the day of the visit. These generally related to mobile species such as birds, mammals and reptiles. They were also asked to describe their utilisation of the terrestrial plant species recorded. These responses were classified into major utility groups, and a list of recorded usages for each species has been compiled.

3.4.3 Identification

Initially, many plant species were unfamiliar to the collector. Samples of these were taken, pressed and referred to the National Herbarium for definitive identification. These preserved specimens were then retained by the Study and used as a reference collection for subsequent work.

3.4.4 Limitations of the Terrestrial Survey

A conceptual problem arises with the use of subjective frequency assessment, in relation to the vertebrates and particularly to birds and reptiles. This is especially true when dealing with species recorded from secondary sources. The density of wild bird populations in Bangladesh is, in international or even regional terms, rather low. Species which are considered common by Bangladeshi standards would, if present in the same population densities, be assessed as occasional or even rare by Pakistani standards, for example. So people's expectations regarding what is a 'normal' population density for a species greatly affect their assessment of its frequency. This is as true for Bangladeshi field workers as it is for the rural people amongst whom they work.

Similarly, the frequency of venomous snakes tends to be over-estimated by villagers and others, because they represent a real and very frightening danger to them. For people living on islands of highland in the floodland areas especially, their homesteads represent the only dry land refuge for animals which would normally be distributed across the floodland during the dry season. So the frequency of venomous snakes in such highland homesteads during the floods is dependent on both the actual population density and (inversely) on the proportion of the area which is highland at peak flood periods. There is therefore inevitably some bias in reporting frequencies of these types of animals, especially when using anecdotal data. It is acknowledged that this inevitably skews estimates of species abundance, but since the degree of bias can only be estimated by more detailed field work, the frequencies of these vertebrates are presented as they were estimated during the field surveys, with no attempt to change them according to any assumed correction factors.

3.5 Aquatic Ecology

3.5.1 Emphasis

The principal investigation in this Study was the characterisation of the aquatic micro-flora and micro-fauna, generally referred to as the phytoplankton and zooplankton. Record of the larger organisms (emergent or submerged plants, birds, mammals and others) were collected by the Terrestrial Ecologist. Records of fish species were not obtained, this being the prerogative of the Fishery Investigation Team. These results are given in their respective volume.

3.5.2 Sampling Method

Plankton samples were collected by towing a 30 micron mesh phytoplankton net for five minutes near the surface of the water, behind hand-operated local boats. The samples were preserved on the spot in 4% aqueous formaldehyde solution ('formalin'), then the species identified at zoological laboratories in Rajshahi and Chittagong Universities. Three 1 ml aliquots were taken from the stirred preserved sample, and the abundance of each species present estimated using a rafter counting cell.

Benthos and neuston were collected by sweeping with a pond net, separated from detritus and preserved in 4% aqueous formaldehyde solution, and identified (to major groups only) at the University Laboratories.

3.6 Data Access

Large quantities of new data have been obtained from the field work, and the opportunities for detailed analysis of these in the future are substantial. In this Study, severe constraints on the time available for such analysis dictate that detailed relationships between environmental variables, the flora and fauna, and the people of the Region, cannot be explored - such work will have to be carried out by future workers. The data collected during the past six months are therefore provided in full in the Data Annex. Given the paucity of data, international interest and currently evolving national policy initiatives copies of this data should also be provided to the Asian Wetlands Bureau and the IUCN.

3.7 Water Quality

3.7.1 Data Sorting

The data from the water samples were assembled on a spreadsheet, then sorted according to each variable, in either ascending or descending orders of magnitude. This technique reveals aggregation of values, and is particularly useful in defining the ranges of variables which may be typical of specific types of water sources. The primary data are presented in Table 4.1.

3.7.2 Limitations of Water Quality Data

A significant constraint on the ecological interpretation of water quality data has been the difficulty in identifying reliable laboratories in which the full range of ecologically important variables could be measured. The absence of data on nitrate, phosphate and soluble silicate on surface waters in samples submitted for analysis is unfortunate, since these are of particular significance in the dynamics of the competition and succession of the phytoplankton.

A secondary data source became available during the course of this Study, through a series of surface water sample analyses obtained by the Jamulpur Priority Project (FAP 3.1). The location of the sampling sites across the Jamuna River from the central area of the North West Region is close to a number of the sites used in this Survey, and the environmental conditions in the Jamulpur area are not considered likely to be substantially different to those along the Jamuna Right Bank. Since this

source provides some data on elements of relevance to this Study (especially phosphate, silicate and iodine), a composite table of water quality variables has been drawn up as an initial summary of water quality data (Table 5.4). This is used as a supplement to the primary data obtained from this Study (Table 4.1).

3.8 Ecological Data Analysis

3.8.1 First Stage Analysis - Pooled Samples

In order to identify general principles and linkages, data for individual sites have been compared to obtain an overview of the principle range of habitats and variables which appear to control the majority of ecological processes within the study area. From this initial screening process, sites have been grouped into specific structural units - for example, ecological zones such as highland, or major habitats such as unflushed beels - and the data from individual sites have been pooled to provide an approximate structural catalogue of species abundances which characterise the main habitats.

In the aquatic survey, some data on the fauna of the bottom mud ('benthos') and on submerged aquatic plant stems and leaves ('neuston') were obtained, but the difficulty of identifying these to species level (generally because appropriate systematic keys are unavailable) dictates that these groups can not be included in the detailed analyses of populations and community structure. Whilst it is acknowledged that this is a defect of this Survey, it is considered that this is not a significantly limiting factor in obtaining an initial over-view of the structure and function of the aquatic habitats.

Indeed, at some sites both groups appear to have been remarkable impoverished - possibly because many aquatic habitats dry up completely every year - and comparison over a short time period would not be useful. Such work needs to be done in much more detail over a very much longer period of time than was available for the present exploratory Survey.

3.8.2 Second Stage Analysis - Diversity Analysis

'Biodiversity' is currently enjoying considerable popularity as a vogue concept, unfortunately with very little comprehension of its true meaning or significance. In ecology the term 'diversity' has very specific meanings, and there are many methods by which diversity is measured. Diversity applies to communities of species, to habitats, and even to the rate of change between adjacent habitats. So specific measures (indexes) of diversity are used for different types of community, for different strategies of ecological analysis, and for different types of data.

3.8.3 The Use of Diversity Indexes in this Study

The interpretation of diversity indexes is a highly specialised branch of ecology. In general, such indexes are calculated after rigorously defined field surveys, and iterative analyses and repeated field studies may be required before a high degree of confidence can be achieved. In the present Study, such detailed site work has not been possible. Consequently, two simple diversity indexes have been used to analyze community structure.

3.8.4 Terrestrial Ecology - Species Abundance in Different Habitats

Quantitative terrestrial ecological data have been collected using abundance classes (ranging from rare to abundant), and consequently are not amenable to complex mathematical manipulation. The diversity of terrestrial animal and plant communities has therefore been expressed using a simple species abundance measure. In this the numbers of species and their relative abundance in each major habitat are expressed on linear scales. This provides a measure of the relative ecological complexity of these habitats - when used in conjunction with data on resource utilisation this analysis reveals which habitats are of importance to human interests, and how resource availability might change following specific interventions.

3.8.5 Aquatic Ecology - Proportional Abundance of the Plankton

In the aquatic ecology survey, a very large number of planktonic plants and animals (phytoplankton and zooplankton) were identified, not only to species level but also in terms of numerical abundance. In many of the sites, these measurements were performed monthly from February to May, providing a very large and detailed database of planktonic species occurrences. Such data can be subjected to more specific diversity analysis, and the Berger-Parker Index of proportional abundance has been applied to the pooled data from the major aquatic habitats.

The time-scale for major (often spectacular) changes in plankton species populations is far shorter than for terrestrial species -usually of the order of a few weeks. Consequently, individual species in some habitats may dominate the plankton in one month and be almost absent in the following one. The Berger-Parker Index is particularly simple to calculate, is comparatively insensitive to sample size, and provides a good indication of dominance, which is the parameter of most interest in planktonic populations. It is an indication of the stability of the community and therefore of resource availability to important groups such as the fish stocks.

The Berger-Parker Index is calculated from the expression

$$I = 1/(N\ max/N)$$

where I is the dominance index of the community
N max is the number of individuals in the most common species
N is the total number of individuals in the sample.

High values for I (typically around 4 or more) indicate a very diverse community in which several or many species exist at moderate population levels. Such communities are typical of relatively stable and constant habitats in which interfering processes are reduced to a minimum.

Low values of I indicate a high degree of dominance by a small number of species, and are characteristic of rapidly changing or disturbed habitats. In rare cases, the index may fall to a value of 1.0, if there is only a single species present.

The monthly values of I for both phytoplankton and zooplankton in the aquatic habitats have been calculated separately, and where there is marked dominance, the species or groups responsible have been identified.

Table 3.1 Site Location for Field Data Collection, Ecological Survey, 1992

Map Ref:	Code	Type	Location	Village	Upazila	District
1	AND	Flushed Beel	Andasuria Beel, Chalan Beel D	Bakapur	Manda	Natore
2	AT1	Atrai R (Temp); HTW	Atrai/Barnai confluence	Sholakura	Singra	Natore
3	AT2	Atrai R (Temp); STW	Atrai/Nandakuja confluence	Chaskor Bazar	Gurodaspur	Natore
4	BAM	Flushed Beel; STW	Bamandanga Beel	Ramvadra	Sundarganj	Gaibandha
5	BAN	Bangali River (Temp)	At Sariakandi	Sariakandi	Sariakandi	Bogra
6	BBB	Unflushed Beel	Beel Baster Beel	Jugepara	Sagata	Gaibandha
7	BUR	Baral River (Perm)	Upstream of Jamuna confluence	Char Pechakola	Bera	Pabna
8	GHA	Ghagot River (Perm)	Outskirts of Gaibandha	Gobindapur	Gaibandha	Gaibandha
9	HAL	Flushed Beel; STW	Halti Beel, Chalan Beel C	Dangarpara	Natore	Natore
10	HAR	Unflushed Beel; STW	Harudangha Beel	Petbata	Pirgacha	Rangpur
11	JA1	Jamuna River (Perm)	Km40 below Indian Border	Jorgas Ghat	Chilmari	Kurigram
12	JA2	Jamuna River (Perm);HTW;DTW	Jamuna/Teesta confluence	Ujan Bochagari	Sundarganj	Gaibandha
13	JA3	Jamuna River (Perm)	Manos Regulator	Rasulpur	Fulchari	Gaibandha
14	JA4	Jamuna River (Perm)	Below Jamuna/Hurasagar confluence	Nayanpur	Bera	Pabna
15	KUM	Flushed Beel; STW	Kumirdaha Beel	Bangarpara	Shagata	Gaibandha
16	MAD	Flushed Beel	Madardaha Beel	Mothor Para	Sagata	Gaibandha
17	NA1	Nandakuja River (Temp)	Above Atrai/Nandakuje R confl.	Holaigari	Singra	Natore
18	NA2	Nandakuja River (Temp)	Atrai/Nandakuja R confl.	Chaskor Bazar	Guradaspur	Natore
19	PAD	Padma River (Perm)	Char at Rajshahi	Durga Ghat	Paba	Rajshahi
20	SIB	Sib River (Temp)	Opposite Andasuria Beel	Chaubaria	Manda	Natore
21	TEE	Teesta River (Perm)	Painalghat Groyne	Shibdev	Pirgacha	Rangpur
22	UTR	Flushed Beel	Utrail Beel, Chalan Beel C	Beel Utraeel	Manda	Naogaon

T = Temporary
P = Permanent

Figure 3.1
REGIONAL ECOLOGY SAMPLING SITES

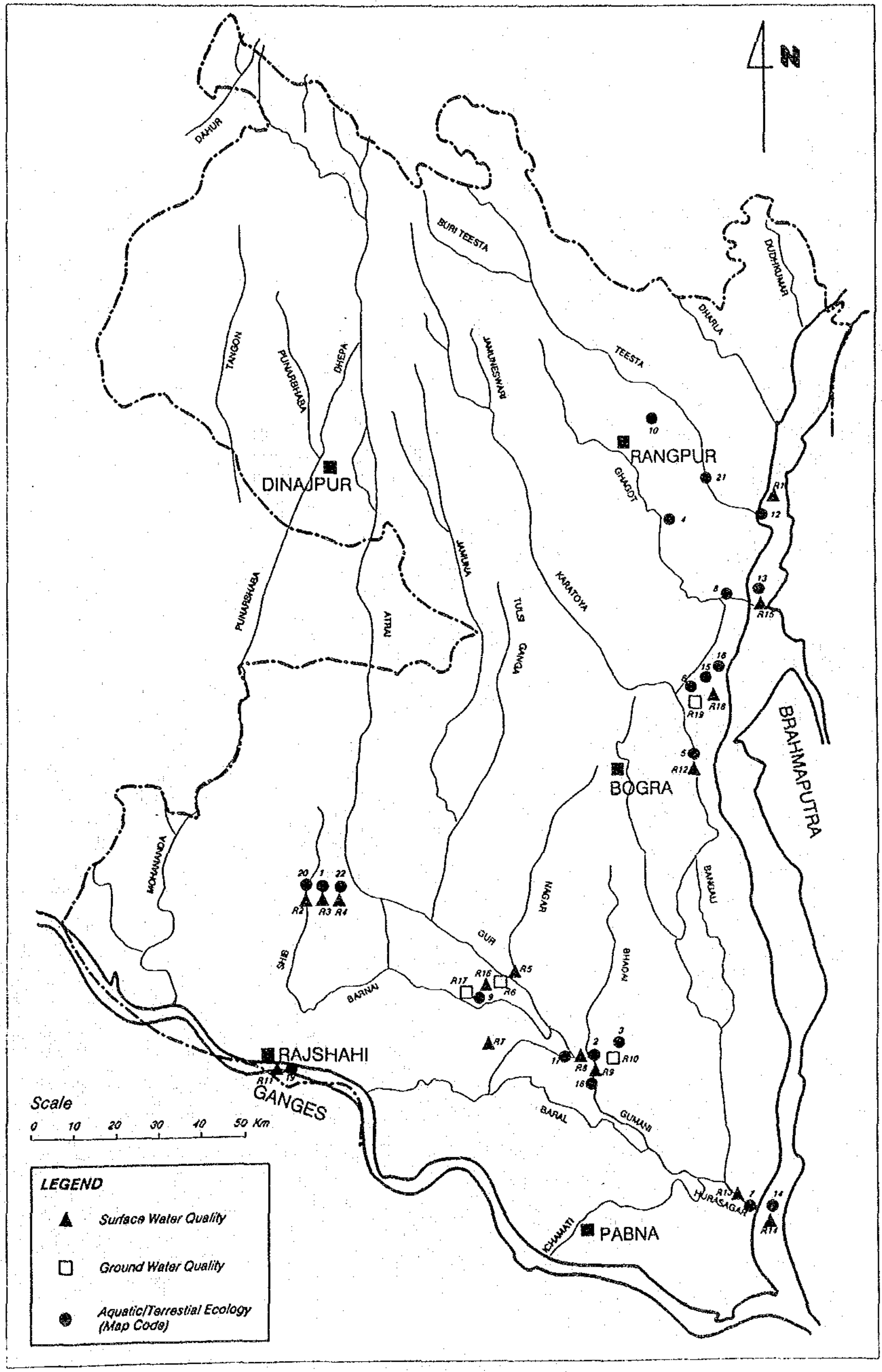
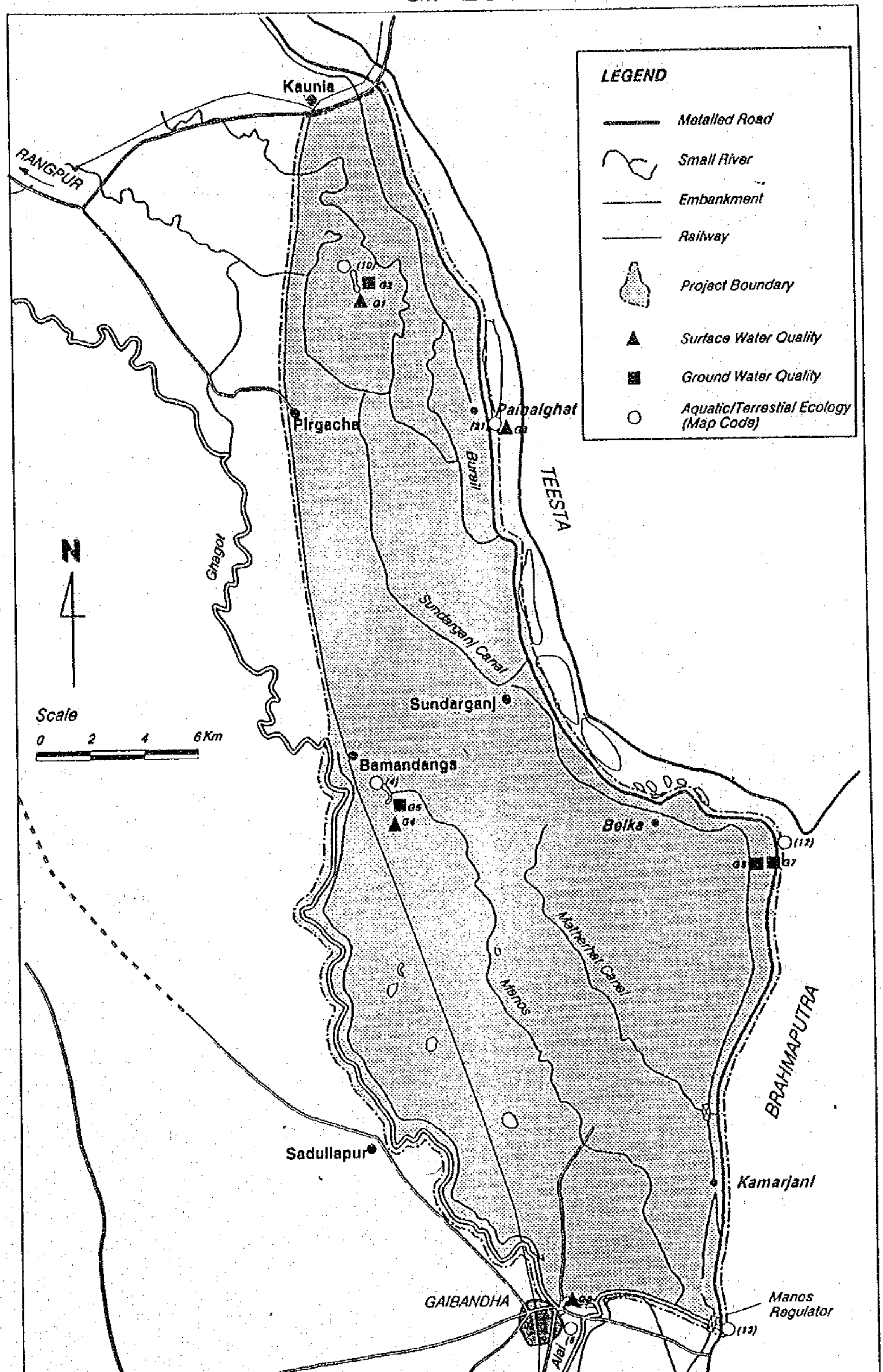


Figure 3.2

GIP ECOLOGY SAMPLING SITES



CHAPTER 4

RESULTS OF THE SURVEY

This Chapter briefly summarises the data obtained during the Study, and presents a number of tables of data which reduce much of the initial mass of data to more manageable proportions for easier comprehension.

4.1 Water Quality

4.1.1 Data Deficiencies

The field data provide some indication of water quality in the rivers, but are defective in that nitrogen levels as recorded appear to be suspect, and analyses for phosphate and silicon were not completed. Consequently, data from recent investigations under FAP 3.1 have been used to supplement the field site data from this Study (Table 5.4). Suspended solids loading can normally be deduced by subtraction TDS (total dissolved solids) from TS (total solids). When this is done with the data provided by the samples collected from this series of fieldwork, however, the results are anomalous, since many of the beels examined are known to have had clear water yet the data imply that their suspended solids levels were as high as those of the major rivers. This is clearly incorrect, and these data have to be rejected. Instead, the experience with the use of the phytoplankton nets by the Limnologist has been used to deduce very approximately the suspended solids loading of the rivers, since increasing silt loading caused the nets to become clogged in a shorter period.

4.1.2 Groundwater

Groundwater has the lowest Ph range of all natural waters in Bangladesh, associated with low dissolved oxygen and comparatively high biochemical and chemical oxygen demands. The levels of plant nutrients and indeed of almost all other dissolved chemicals except iron are very low. The most significant exception is ammonia, which is present in greater concentrations in groundwater than in surface waters. In all cases for which records are available, iodine is present at a more or less constant background level of around 50-90 nanogrammes per litre (i.e. approximately 1 mg in 10 to 20 cubic metres of water).

4.1.3 Permanently Flowing Rivers

The water quality of the permanent rivers is significantly different from the preceding two classes. Jamuna River water is soft and poorly buffered, with a pH range of 7.7 to 8.2. Nitrate and phosphate are adequate to support phytoplankton growth. However, the heavy silt loads carried during the flood season by all rivers, and by the Teesta and Jamuna Rivers during most of the dry season as well, prevent the penetration of light which is essential for the growth of phytoplankton. Consequently, nitrate and phosphate - both essential plant nutrients - are in higher concentrations in the permanent rivers than in any other surface waters, since there is no plant activity which would remove them from solution. Ammonium levels are, however, comparatively low.

The oxygen levels of the principal rivers are higher than those found in any other type of water source in this study, ranging from 8 to 8.7mg/l. High oxygen concentrations are normally associated with high photosynthetic activity, but in its absence in these rivers it appears that the high turbulence is sufficient to facilitates full oxygen saturation through surface adsorption alone.

Silicon levels are also adequate to support phytoplankton growth. Silicon is an essential element for the multiplication of the diatoms (Phytoplankton: Bacillariophyceae). In its absence, the 'Blue-green algae' (Phytoplankton: Cyanophyceae) are able to compete effectively with the diatoms. This can lead to blooms of Cyanophyceae, which release powerful neurotoxins able to provoke severe reactions in people drinking the water, as well as extensive fish mortalities.

4.1.4 Padma River Water Quality and the Farakka Barrage

The quality of Padma River water is not significantly different from that of the Jamuna except that the total suspended solids were slightly lower than the levels in the Jamuna. It is possible that this small difference may have allowed slightly greater light penetration, and hence the development of the stronger plankton population, but the evidence is weak. Unfortunately, the absence of data on nutrient levels in both rivers prevents further interpretation, and the reason for the high productivity of the Padma River is obscure.

4.1.5 Temporary (Seasonal) Rivers

During the dry season the floodplain rivers become greatly diminished in flow, and many cease flowing altogether. Many of the Atrai Basin tributaries are of this type, and degenerate into a series of static pools which are used for a variety of purposes by the rural people and their livestock. Chemically, these pools are indistinguishable from permanent standing waters such as the beels and many ponds. They have a pH of around 7.4 - 8.0, dissolved oxygen levels of 5.5 - 8mg/l, and virtually no dissolved nitrate or ammonia nitrogen, nor phosphate.

4.1.6 Bacterial Quality

All sources are liable to contamination with faecal bacteria (Coliform bacteria). However, deep tubewell water may be almost free of coliform, but shallow tubewells frequently show elevated levels if they are constructed without adequate sealing around the wellhead. It is noticeable that flushed beels (i.e those which are inundated by overflows from the rivers during the flood season) tend to show higher coliform counts than unflushed beels. Permanent rivers may have very high coliform counts at some locations, reflecting local sources of urban sewerage discharges. The main reported human and fish pathologies for each water quality sampling site are presented in Table 4.2.

4.1.7 Biocide Residues

Information was sought from local farmers on the main types of fertilisers and biocides used around the sample sites, and on their recollections of the main types of human and fish pathologies. The data on these topics are shown in Table 4.3.

No data on the incidence of biocide residues in surface water or groundwater in the Regions have been available. Since the issue of potential contamination of these waters by biocide residues is a matter of widespread speculation, a sample of water from Bamandangha Beel, and two from nearby shallow and deep tubewells, were taken and analysed for residues by the Bangladesh Atomic Energy Commission Laboratory. They were extracted with acetone/hexane, dried and run through a fluorosis column using petroleum ether/dichloromethane eluent. The final estimation of active residues was

made using a glass column packed with 1.5% OVi7 plus 1.95% QFI on Chromosorb WHP, using nitrogen carrier gas at 225 degrees Celsius. Spiking samples with DDT and Dieldrin was used to determine residue concentrations and recovery rates.

In all samples, no organophosphate resides were detectable. Dieldrin was present in the surface water at 0.64 ng/l (1 nanogramme = 1.0 x 10^{9}g, or one part per billion), whilst DDT was detected at 1.5 ng/l. Parallel work on the levels of these residues suggests that there may be a concentration factor of in the region of thirty in cow's milk, compared with these background levels in surface water.

4.2 Terrestrial Biology

4.2.1 Major Habitats

The major habitats are defined very clearly by the flooding regime to which a location is subjected. There are therefore three distinct terrestrial zones, each with their peculiar habitats, and these are characterised as follows:

A. Lowland Zone

i. River Banks and Channels

Plant species abundance is low, with a dominant community of semi-prostrate or small species able to tolerate exposure to fast-flowing currents. Larger plants (shrubs and trees) are absent. The resource value of these species appears to be very low (Table 4.4).

The animal species abundance is much higher, and there is a fairly rich bird fauna, inevitably including a large proportion of fish-eating species. The reptilian fauna is also strongly represented (Table 4.5.)

ii. Charlands

The flora of the charlands is remarkably diverse. It includes a number of species which are abundant but for which there is no known human use. These are generally pioneer species such as Ranunculus, which are able to form dense mats of vegetation which stabilises the char sands. Their poisonous bitter juice prevents them from being grazed by livestock (Table 4.6.)

The vertebrate fauna of the charlands is almost confined to birds. During the period of study (February-April 1992) the number of species recorded was low - it is not known whether this group would be significantly augmented at other times of the year (Table 4.7.)

B. Floodland

i. Agricultural Land

Agricultural fields themselves provide the least species abundance of all the habitats examined. Extraneous plants are ruthlessly weeded out, whilst the monocultures themselves provide little shelter for animals. The small banks and pathways forming the field margins are much more diverse, and provide the only habitats for potential pest control agents (Tables 4.8, 4.9.)

ii. Beels

Most beels contain virtually no aquatic macrophytes. In those which do - for example, Andasuria Beel - the species diversity is high, unless water hyacinth (Eichornia crassipes) invades the water, in which case all other species are eliminated because sunlight is unable to penetrate the hyacinth blanket (Table 4.10).

The main vertebrate fauna consists of birds, but water-loving reptiles are frequent, although they tend to be less common in those beels which are almost completely reclaimed for agricultural use during the dry season, e.g. Halti Beel (Table 4.11.).

iii. Floodplain Homestead Areas

Some homesteads are situated below the elevation of peak flood, so become inundated for short periods during the wet season. In some areas, they may be protected by an embankment, and the Study examined a pair of homestead areas on either side of an established embankment in order to assess whether the erection of an embankment has any significant effects of the terrestrial species present.

In both sites the species abundances were virtually identical, and far below those of highland homesteads. Most of the animals species recorded can be regarded as commensals - i.e species which live in close association with man. In terms of resource availability, neither homestead has a great deal of variety, and these areas must be considered as extremely impoverished. They are characteristic of the floodland areas themselves, and bear almost no ecological resemblance to highland habitats (Table 4.12 - 4.15.)

iv. Embankments

Compared with the floodland on which they stand, the species abundance of embankments is remarkably high. Animal species are especially prominent, and the embankments clearly form important linear habitats for a wide variety of terrestrial animals. The high frequency of small mammals, including pests of stored grains such as the mice, and the cool microhabitat provided by cracks in the embankments, attract reptiles including occasional venomous snakes (Table 4.16, 4.17.)

C. Highland

i. Highland Homesteads

In terms of species abundance, the highland homesteads stand far above all other habitats. They provide a wide range of micro-habitats in which many plants and animals can survive. They provide the greatest opportunity for species conservation, since almost all the species found in the floodland are also present, and in somewhat greater density, in the highland areas.

The wide variety of fauna provides a remarkable range of resources for the human population, and it is known that many of the resource species are actively established, cultivated and protected by the people. Their uses range from medicinal through utilitarian to cultural and religious, with the two main religions often sharing use of the same species (Tables 4.18, 4.19.)

ii. Refuges

Although not specifically provided as refuges for wildlife, there are several small habitats which are able to provide some degree of sanctuary for them. Of these, the permanent ponds in highland are colonised or frequented by a range of birds more usually associated with the open fields and floodlands - for example the egrets and kingfishers - whilst aquatic reptiles also use these small ponds as their habitats, preying on the many amphibians which are attracted to the water (Tables 4.20, 4.21.)

On some floodlands close to the flooding limit there are small clusters of trees or bamboo thickets which also offer some degree of cover for the shyer animals. Obtaining some idea of the species present in such thickets is extremely difficult - their presence could be detected by sound, but their identity remains a mystery. However, near one such cluster the prints of a very small deer were noted, a type of animal not seen by the local farmers for many years (Table 4.22.)

Whilst the bamboo clusters tend to be monocultures, other less dense woody refuges provide a range of plant species, a substantial proportion of them providing herbal medicines for common ailments such as gastro-intestinal disorders and skin infections (Table 4.23.)

4.2.2 Summary

The species abundances of the floodland habitats are far lower than those of the highlands. Even the embankments - relatively recent and small habitats - are more diverse than the flooded areas. The detailed pooled species lists for larger plants and vertebrates are presented in Tables 4.24 and 4.25. The recorded utilities of many of the plant species are also shown in Table 4.24.

The highland provides the greatest range of resources, and shows every sign of good traditional management practices aimed at preserving this diversity of resource values.

4.3 Aquatic Biology

The aquatic habitats of the Region can be grouped into five main types. These are described individually below, with a summary of their principal phytoplankton and zooplankton communities. Since the plankton communities are so complex, summaries of the dominant species are provided in Table 4.26 and in the Analysis (Chapter 5, Table 5.7 - 5.15). Detailed lists of species occurrences and frequencies are provided in the Data Annex (Annex A; Tables A1 - A23.)

4.3.1 Permanent Rivers

The plankton of the permanent rivers is regulated by the silt loading of the waters. The Teesta has a relatively high silt load as early as late February, whereas that in the Jamuna increases over a month later, in about April. In the Padma, the effect of the Farakka Barrage is to delay the rise of the river, and the silt loading is moderate and fairly constant until at least May. The Baral (noted as Burail in original data sheets), at the lower part of the Atrai Basin, has almost the same silt load as the Jamuna in February/March, and like the Jamuna its plankton is in severe decline by mid-April.

During February, the phytoplankton of all the principal rivers is mainly represented by the green algae (Chlorophyceae), but their dominance is weak (BP Index 3.45). In the Teesta, their dominance is broken by the development of populations of diatoms by April, but by May very few algae are able to survive the increasingly silty waters, and phytoplankton is on the verge of disappearing.

The zooplankton is dominated by Rotiferal for most of the spring, but they are temporarily exceeded by their primary predators, the crustacea (Copepoda and Cladocera) during March. By May the whole of the Teesta/Jamuna River complex has lost its zooplankton. However, in numerical abundance, the decline in zooplankton populations in the Jamuna starts as early as late February, whilst in the Teesta itself the zooplankton is already in severe decline by that time.

4.3.2 The Padma River - a Disturbed River Habitat

The situation in the Padma River is completely different. The Chlorophyceae dominance is broken only temporarily in April by the expansion of the Chrysophyceae population, but the Chlorophyceae regain dominance in May. The phytoplankton populations only start to decline in May, and throughout the dry season their populations are considerably higher than those in the Jamuna River or the Teesta. The relative importance of the Cyanophyceae ('Blue-green algae') in the Padma River is greater than that in the Jamuna; this group is even less common in the Teesta phytoplankton.

The zooplankton of the Padma is dominated by Rotiferal throughout the dry season, with occasional species population maxima developing and then dying away, as is shown by the fluctuating but generally moderately high diversity index.

4.3.3 The Temporary Rivers

In the temporary rivers, the phytoplankton is more diverse than that of the permanent rivers from February to May, reflecting the higher water transparency of these static waters. In the early part of the period the diatoms (Bacillariophyceae) and the Dinophyceae are common, but these give way to the Chlorophyceae by May. The dominance of the latter is, however, short lived because the flood waters bring an end to phytoplankton growth as water transparency falls to very low levels by the end of May. The decline in total numbers of individuals is already marked by April in the Atrai system. In the Sib, the decline starts somewhat earlier, possibly due to turbidity resulting from early rainfall and run-off from the Barind Tract to the west.

The zooplankton in these waters is dominated by the Crustacea until April, when they are overtaken by Rotiferal. Zooplankton numbers in these waters do not fall significantly by the end of May suggesting that they are less sensitive to suspended silt than the phytoplankton.

4.3.4 The Permanent (Unflushed) Beels

The permanent beel phytoplankton was dominated by the Cyanophyceae throughout the period of study, only giving ground in some beels (such as Beel Baster Beel) to the Chlorophyceae in May. In others (e.g. Harudangha Beel), the Cyanophyceae retain dominance - indeed, these permanent beels appear to contain a higher proportion of Cyanophyceae than any other water type examined in this study.