In addition, the lack of these inter-crops represents a loss of a potential source of some of the highest nutritional value fodder crops. Since very poor livestock nutrition, especially at the end of the flood season, is known to be a major cause of loss of draft-power capacity in Bangladesh, any practice which can improve this situation should be considered as a major priority.

(c) Lowered Water Tables and Tree Crop Productivity

The impact of reduction in waterlogging on the uptake of nutrients promoted by the tree-soil fungal association is difficult to quantify. The habitats which would be most beneficially affected would be the floodlands, but it is notable that tree plantation is rarely practised on flood-prone land, even behind embankments. This is presumably because the reliability of protection is inadequate to ensure that trees will never be exposed to severe flooding, which could kill them before they mature. This assumption is supported by the finding of a lack of any significant change in the terrestrial ecology of the homestead areas on the protected side of an established flood defense embankment on the Jamuna Right Bank.

It is possible, however, that trees planted on many smaller highland areas which are close to the full flood levels - for example, those small homestead areas which have been built up deliberately - would benefit from a reduction in the very high groundwater tables after FCD. This would allow the fungal mycorrhizal association to operate throughout the year, and presumably promote a more effective relationship than would be able to develop under conditions which are unfavourable for up to six months out of every year.

6.8 The 'Fish Versus Rice' Controversy

6.8.1 The Myth of the 'Jamuna River Fish Stocks'

It is clear that there is no energetic basis for regarding the fish which live in the Jamuna River during the dry season as 'river fish'. Indeed, it is reasonable to propose that there can be no justification for referring to the separate existence of a 'river fish' resource when dealing with such abnormal river systems. The term is highly misleading, since it implies that these fish have an intrinsic and separate viable existence. Since the energy available to fish living in the principal rivers in fact originates almost entirely from the floodland, and is only directly available there, the principal rivers should more properly be regarded as convenient short-term refuges from extreme dry season conditions on the floodland feeding grounds. In strict fishery terms, they are simply stewponds for the temporary storage of that part of the stock which happens to have taken refuge there during an adverse period.

Only those fish species which eat other fish are therefore able to exist permanently in the rivers without ever needing to travel onto the floodlands. They can survive by relying on other fish to travel to the feeding grounds, returning with convenient packages of biochemical energy - their own bodies - which the predatory fish can use for their own requirements. But of course, even these species would disappear very rapidly if their prey were unable to gain access to the feeding grounds every year.

6.8.2 The Need for a Paradigm Revision Relating to the Role of Fish in Floodland Ecology

This point may seem academic. It is not. It is in fact a vital concept in the understanding of the linkages between the terrestrial and the aquatic habitats. It is necessary to completely revise the paradigm under which the river fish resource is currently regarded and managed. 'River fish' are in

fact floodplain fish which take refuge in the river when environmental conditions become intolerable, but many members of their species also take refuge in the beels during the same period of the year. In this respect, therefore, **both rivers and beels are part of an integrated network of fish refuges,** and their relative importance is proportional to their residual areas at the end of the dry season.

6.8.3 Implications for FCD Interventions

The issue is therefore NOT whether and how FCD interventions should be planned to provide river fish with access to the floodplain. Rather, it is that they should be planned to provide floodland fish with access to the rivers and beels as refuges during the dry season. Viewed in this light, the preservation and management of the floodland fish stocks AS A WHOLE rests on the need to maintain access to dry season refuges and to energy sources on the floodland during the wet season. Clearly, such a view favours the development of compartmentalisation, coupled with the preservation of the integrity of as many beels as is feasible, and a suppression of the excessive encroachment by agriculture as is happening at Halti Beel.
Fish stocks within compartmented areas should be recognised as an important flood-season resource, not purely because they are seen as a food for man, but because they are an integral part of the energetic regime of the floodplain. They probably represent the most efficient system available for maintaining energy flow at its optimal level, at a time when other terrestrial energy transfer mechanisms are severely inhibited by soil saturation.

This is not to deny the relevance of the issues relating to the recruitment of the major carps, which are unusual in the floodland fish stocks in that they travel upstream in the principal rivers to more remote spawning grounds. Such specialised needs certainly do need to be addressed specifically in the planning of flood control policies and structure. But the central issue remains that if fish are to continue to be an integral part of the fauna of the floodland, and therefore to play an economic role as a resource for human exploitation, then decisions need to be made as to what share of the total energetic capacity of the floodlands should be allocated to them. Such decisions have to backed up by an effective management administration which ensures that this energy allocation is preserved.

6.9 The Importance of the Wetlands of the North West Region

6.9.1 The Wetlands and Agriculture

There can be no doubt that the network of beels and rivers in the Region constitutes an essential resource for the preservation of the integrity of the unique and highly specialised fish community of the Jamuna floodplain. Whilst most Bangladeshi fish species also occur elsewhere, the combination of species and their extraordinarily complex role in maintaining the energetics of the floodplain make the Bangladesh wetland system of extreme ecological importance.

Indeed, it is precisely this energetic relationship upon which much of the rural economy is founded. Without the activities of the fish on the floodlands during the flood season, a large proportion of the energy stored in plant and animal remains and crop residues would be lost, because the more inefficient glycolytic oxidation of these residues would be much more prominent, and the overall energetic efficiency of the ecosystem would be greatly diminished.
So the value of the fish does not reside solely in the value of the fish taken by fishermen and others; they are of considerable economic importance also to the agricultural sector, which because of flooding is forced to remain idle during a significant part of the year. At that time, the floodland fish take over the role of nutrient and energy recycling which is the prerogative of the soil fungi and bacteria during the dry season.

In this role they are assisted by the Cyanophyceae, the 'blue-green algae' which are able to capture nitrogen and fix it in the soil in a slow-release form which is of very high value to the agricultural sector. Without the floodland fish, this process would be reduced, because the fish excrete waste products from their own digestion processes which provide the algae with the trace nutrients which they themselves need to function.

6.9.2 The Chemical Option for Agriculture

This is not to say that it is not perfectly feasible to adopt an agricultural system which banishes the floodland fish in the interest of ever-increasing crop production - the principal potential effect of many of the proposed FAP scheme interventions. But this will inevitably result in the conversion of a biochemically-based agricultural system to a chemical system. Whilst both are intrinsically viable, only the ecological system (the biochemical option) is self-sustaining, benign and self-regulating.

The chemical option may produce more food for people in the short term, but in the long term presents significant hazards for soil structure and stability, groundwater quality, and public health. Moreover, it preempts the possibility that in future agriculture will expand its horizons to develop a wider species base from which to obtain foods for the people. Chemical agriculture almost inevitably reduces species diversity - the evidence from this study demonstrates clearly the loss of diversity in monoculture agriculture, and this relates to systems which have not yet come to rely heavily on biocides to control competitor species ('pests').

6.10 The Requirements of the Ramsar Convention

6.10.1 Ecological Values

The standard classification for wetland habitats is issued under the Ramsar Convention, to which Bangladesh has assented. Under the Convention each Contracting Party

"shall designate suitable wetlands within its territory for inclusion in a list of 'Wetlands of International Importance' ... in terms of ecology, botany, zoology, limnology or hydrology."

The wetlands of the NWR are greatly affected by human interventions, and in terms of their value as habitats for terrestrial species or wildfowl there in unlikely to be any validity in classifying them as being of special importance. However, under the criteria to be applied in judging the intrinsic value of specific wetlands, Criterion 1(c) specifies that a wetland should be considered internationally important if it is a 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.

In view of the relationships outlined above, there can be no doubt that the Region's wetlands should be designated as Ramsar Sites under Criterion 1(c). In South Asia, only the Indus Basin has a comparable fish species complexity and relationship with a major floodplain, and the ecology of that system is now so damaged that it is beyond recovery. Indeed, the increasing problems of salivation and population pressures in the Indus Basin are so serious that the ichthyofauna of Pakistan is liable to decline very severely within the next decade or so. The Jamuna floodplain fish therefore represent the only example of a complex ecosystem in which the terrestrial and aquatic habitats are clearly and intimately linked, and in which each environment is so dependent on the other.

6.10.2 The Role of the Wetlands in Maintaining Genetic Diversity

Criterion 2(b) of the Ramsar Convention specifies that sites of international importance are those which maintain the genetic or ecological diversity of a region. In terms of ecological diversity, the wetlands are clearly different in type to the terrestrial floodland habitats, and their reclamation would certainly represent a major reduction in habitat diversity on the floodplain. However, their role in supporting the very high species diversity of fish indicates an extremely high value in the preservation of genetic diversity in Bangladesh.

The present strategy in aquaculture development demonstrates the hypnotic drive for uniformity which Ramsar specifically aims to reduce. Currently, almost all international development policy in aquaculture centres on the introduction of exotic species such as the common carp, silver carp, grass carp or the ubiquitous Tilapia, merely because it is easier to do so than to exert an effort to develop methods of culturing indigenous species. So the opportunity to exploit the vast genetic reserves of the indigenous species is neglected, and species with fully as much potential as the exotics may be lost before any attempt is made to discover their virtues.
Indeed, in Chalan Beel the frequency with which waters stocked with exotic fish species by the Dept of Fisheries and the Third Fisheries Project are washed out by breaches in the adjacent embankments demonstrates the lack of appreciation of the dangers of such ill-considered introductions and narrowness of vision. Common carp are no better than many other indigenous fish - indeed, they are all too frequently rejected for their very poor culinary qualities. Their deliberate release into waters from which they can easily escape and compete with indigenous fish species is little short of ecological vandalism. In Australia they have totally dominated a number of Queensland rivers to which they were introduced, to the extent that they are now considered to be a major ecological disaster, and a number of indigenous fish species are now endangered as a direct result of their introduction.

6.10.3 Wetlands of Special Value as the Habitat of Animals at a Critical Stage of Their Biological Cycle

Criterion 2(c) clearly applies to the floodland wetlands of the Region, since the beels act as dry season refuges for the fish which require access to the floodlands during the spawning season. It is relevant to direct attention to this role of the wetlands, as it contrasts strongly with the conventional view that the beels are important as fisheries in themselves. Removal of access to the beels as refuges, coupled with obstruction of access to the rather less congenial environment of the rivers through FCD interventions, presents a major threat to the survival of the fish of the floodlands. Without such refuges the availability of energy sources for fry on the floodlands during the annual inundation becomes irrelevant, since there will be no bloodstock to produce the fry.

6.10.4 Wildfowl and Wetland Birds

The Ramsar Convention also adopts the criterion of the presence of wetland birds which are indicative of wetland values, productivity or diversity (Criterion 3(b)). A number of species observed are so indicative - although only present in small numbers, they are qualitative (as opposed to a quantitative) indicators, and therefore indicate that the wetlands should be designated.

CHAPTER 7

THE ECOLOGY OF THE FLOODPLAIN FISH

7.1 Introduction

The Ecological Survey is seen as a Study running parallel and complementary to the Fisheries Study. However, the latter deals more specifically with the exploitation of the fisheries as resources, and it is appropriate to include in this Survey some consideration of the ecology and energetics of the fish stocks, as they form an integral part of the ecology of the aquatic and, as has already been discussed, the terrestrial habitats as well.

Much of the material which follows has been accepted for publication by the Bangladesh Zoological Society, and will appear in the University Journal of Zoology of the University of Rajshahi. It is included in this Study as it is the first analysis of the energetics baseline of the floodplain fish stocks. It also introduces the use of the MIKE11 hydraulic model as an ecological tool; this model is used almost universally in the FAP and related schemes in Bangladesh, as an engineering tool and for flood forecasting, but the appropriate methodology has only recently been developed. (A detailed description of the methodology is included as Annex B).

7.2 The Dynamics of the Major Carp Populations

7.2.1 Spawning Behaviour

Basic existing research for many of the riverine fish of the Indian sub-continent, including the Major Carps, begin an upstream spawning migration from about February each year, whilst others undertake lateral spawning migrations onto the floodplain as the water spills over the banks. A number of factors are known to be involved in initiating the release of eggs and sperm, including the change in water quality and velocity caused by the start of the monsoon rains and spring snowmelt in the Himalayas, and the phase of the moon.

The eggs are released and fertilised in short-lived episodes, extending over only two or three days at a time, between late April and early July, and are carried downstream as planktonic eggs and larvae. They are swept onto the floodplain where they develop into fingerlings, and spend several months feeding on algae, small invertebrates and detritus before returning to the rivers and beels (permanent depressions) where they spend the dry season.

7.2.2 Recruitment Potential

The recruitment potential of a year-class of fish is a measure of its capacity to colonise a habitat. For floodplain species, this refers to the abundance of viable eggs or fry (year class 0+) in the water which covers the floodplain at the start of the floods. Older year classes are of course also involved in colonising the floodplain during the wet season.

Many seasonally-spawning freshwater fish release eggs episodically, and the fertility of eggs released towards the end of the spawning season tends to be lower. So the recruitment potential is not normally distributed in time, but is strongly skewed towards the weeks immediately following the first spawning activity.

7.2.3 The Importance of Synchronicity

This coincident timing, or synchronicity, is a physiological response to the onset of conditions peculiar to this type of river system. The spawning and fertility pattern (Figure 7.1(A)) ensures that maximum recruitment potential (Figure 7.1(B)) coincides with the start of the inundation of the floodplain (Figure 7.1(C)), and that it is sufficiently flexible to allow recruitment of the seasonal feeding grounds under a wide range of normal fluctuations in flood levels and timings.

The life spans of the species are of course sufficiently long to enable them to survive occasional years in which the floods are abnormally low or late. Under the undisturbed flooding regime, recruitment potential is maximised, and full utilisation of the productivity of the floodplain resource is achieved. Any event which delays the timing of the rise of the flood is potentially damaging to the floodplain fisheries, since it reduces the synchronicity of inundation and peak recruitment potential. Partial flood control reduces recruitment because the opportunity of the fry to disperse over the floodplain is lost. In addition, the length of the feeding period for all year classes is reduced, and the actual productivity of the floodplain falls (Figure 7.1(D)).

Even minor interventions may cause a delay in inundation, so that the land is flooded only after the period during which recruitment is possible. In such cases, no matter how much of the floodplain is covered, year class 0+ productivity for that year (Figure 7.1(E)) will be virtually eliminated. There will be some inward migration of all year classes from adjacent areas, but this will be sub-optimal and may reduce fish productivity in those areas. If synchronicity is destroyed over an extended period, then repeated recruitment failure may set up a positive feedback loop which will cause the stock to decline catastrophically.

7.3 The Use of Hydraulic Modelling in Ecology in Bangladesh

7.3.1 Fishery Dynamics

The importance of recruitment, dispersal and resource utilisation as separate processes in the dynamics of the floodplain fisheries of Bangladesh is poorly appreciated (World Resources Institute, 1990). The belief that the major impacts of flood control result principally from changes in the area of inundated floodplain assumes that there is a linear relationship between the total flooded area and the fish yield, and that changes in one will be reflected in the response of the other. This is only so if recruitment is adequate and the stock is resource-limited. This assumption is unjustified, since both recruitment and resource availability on the floodplain have been profoundly changed by human activities.

Intuitive assessments of the probable impacts of flood control interventions are unreliable. Correctly applied and interpreted, hydraulic modelling is the only methodology presently available which is capable of revealing the subtle changes in timing, duration and levels which are likely to occur in river systems after intervention. It provides a powerful new ecological tool which allows a far more systematic approach to floodplain resource analysis. The MIKE 11 model is now widely used for the engineering appraisal of flood control interventions in Bangladesh, but its practical application as a tool in ecosystem management has only recently been developed (Cross D. 1991a).

7.3.2 Interpretation of MIKE 11 Model Output

Whilst there are considerable opportunities to develop interpretation methodology in a wide range of environmental fields such as public health, water quality, and navigation, the application of modelling to fish stock management is briefly described below.

Hydrographs of the probable changes in flooding at a number of points on the Dhaleswari River complex under different intervention scenarios reveal potential changes in the time of the rise and fall of the floods, their duration and their levels. An option which causes only slight changes in the timing of the rise of the flood in a low-flow year (Figure 7.2(A)) may have little effect on recruitment potential, and the delay may be no more significant in a high-flow year (Figure 7.2(B)). The duration of flooding may be marginally reduced in low flow years, causing a slight decrease in fish productivity, but somewhat more strongly affected in high flow years.

When flood levels are reduced by interventions, the area of deeper water is reduced. The area-elevation curves for the floodplain are concave for the inundated areas, and the areas of very shallow water which provide a refuge for the 0+ year class may even increase after moderate intervention. This discovery, which is counter-intuitive, has considerable sociological implications, since it may improve the ability of casual fisherfolk to compete with the professionals (Cross D.1991a)

After more drastic interventions, the loss of synchronicity causes a dramatic depletion in all the processes which are involved in year class 0+ fish production, and very severe effects on recruitment of older fish year classes. In high flow years, 0+ recruitment may be almost totally eliminated, due to the long delay in the rise of the floods (Figure 7.2(D)). The reduction in duration and extent of flooding would provide very little potential for resource utilisation, even by those fish (mostly 1+ and older year classes) which do arrive to exploit the area late in the flood cycle.

In low flow years, the impact of major intervention could be catastrophic (Figure 7.2(C)). Total recruitment failure would be accompanied by an almost complete loss of resource availability resulting from the decrease in both the duration and the area of flooding. Older year class fish will only be able to use the terrestrial resources on a much smaller area for a month or two at most.

7.4 The Significance of Energy Transfer to Fish Populations Living in the Rivers

The principal rivers have insufficient intrinsic energy inputs to maintain the large fish biomass which is widely regarded as representing the 'river fish' stock, and as has been discussed above (Section 6.8.2), it is more appropriate to regard almost all of these fish as floodland fish which have become temporarily trapped in the rivers until new energy sources become available to them at the start of the next flood season.

The significance of this energy transfer mechanism in the floodplain ecosystem has not previously been recognised in the country, although the Bangladesh Carbon Group has described related chemical aspects (Safiulla and Huq, 1990). Energy harvesting during the wet season considerably supplements the comparatively low level energy source (photosynthesis) which is directly available to the aquatic ecosystems during the dry season.

It also explains the apparent anomaly of the remarkable diversity of fish species which are present in these rivers, which have such low habitat diversity. Niche hypervolume allocation in the habitat-poor dry season rivers would normally be expected to produce strongly skewed species abundance indices. That there is such a wide range of common species reflects the periodic availability of the many energy-rich sources and habitats of the floodplain during the wet season, especially before man's activities affected the natural ecology of the region.

7.5 Summary of Major Carp Biology

In the floodplain fisheries of the Indian sub-continent, synchronicity of the periods of maximum recruitment potential and the rise of the floodwater ensures that stock recruitment capacity and resource utilisation are maximised. The aquatic ecosystem is an open self-organising system maintained far from thermodynamic equilibrium by minimising its rate of entropy production. It accumulates energy by exploiting the terrestrial ecosystem through the annual cyclic energy-harvesting actions of the floodplain fish species. This enables it to function effectively during the energy-poor dry season.

When there is a major interference in synchronicity, the integrity of all energy transfer processes dependent on it is destroyed, and profound and irreversible changes occur once the disturbance exceeds a critical level. The effect of severe environmental pressures on the fish stock will be to drive the system beyond its first bifurcation point, leading to a sudden decline in species diversity and productivity as the energy transfer efficiency falls to a new and significantly lower state.

The use of hydraulic modelling reveals that even minor flood control measures may cause subtle disruptions to synchronicity, and allows much more precise identification of the potential ecological impacts of flood control interventions. Local and upstream interventions which reduce the synchronicity essential to stock recruitment represent a major threat to the integrity of the energy transfer system, and could result in potentially catastrophic losses in diversity, productivity and energy transfer efficiency.

The present level of energy capture represented by the universal practice of harvesting the fish as they retreat to the river at the end of the wet season may now be approaching critical dimensions, leaving relatively little capacity to survive even minor additional interventions.

The anomalously high species diversity of the river fish stock may therefore be regarded as a survival mechanism, permitting it to maximise the exploitation of energy sources on the floodplain, rather than an evolutionary device permitting the species to occupy extremely small niche hypervolumes in the dry season river itself. For many species, the dry season river is simply an extreme habitat, to be tolerated and survived until the arrival of the next inundation. The linkage between the simplification of the terrestrial habitats by intensive agriculture and the decline of the floodplain fisheries therefore become clearer, since man's activities on the land eliminate many of the niches essential to aquatic species during the floods. These relationships reveal the practical value of biodiversity to mankind rather more tangibly than the arguments commonly used to support the more abstract objective of preventing a decline in genetic diversity.

7.6 How Flood Control Activities Disrupt Energy Transfer

7.6.1 Fry Capture and the Receding Flood Fish Harvest

Removing floodplain fish before they return to the rivers is a relatively coarse intrusion into the energy transfer mechanism, and may even be one to which the fish stock is relatively resistant. However, there is another point which is peculiarly susceptible to disruption, and one which almost all physical flood control activities inevitably attack. This is the movement of fry from the rivers out onto the land at the start of the annual floods.

If the synchronicity of recruitment and flooding is interrupted, even by delays of only a month, the recruitment potential may become so low that the energy transfer efficiency of the system is disrupted for the following year. The natural resilience of the stock is such that such periodic failures can be absorbed, and no permanent impact will occur. However, if after a flood control intervention the disruption is repeated for a number of years, it will so reduce the energy content of the aquatic ecosystem that it may be forced beyond its first bifurcation point, so that it will flip irreversibly to a lower steady state.

The assumption that flood control interventions may only affect fish which are thought to be particularly dependent on the floodplain hydrology, such as the Indian Major Carps, is certainly misplaced. Interruption of the energy transfer process affects all aquatic species, and not just those which make up the major energy transfer pathways.

It is therefore vital to be able to identify both the extent of any loss in synchronicity and the frequency with which sequences of low flood years occur which could result in catastrophic cumulative impacts on the population dynamics of the stock. Hydraulic modelling is the only system so far available which allows these factors to be identified with any degree of reliability.

7.6.2 The Effects of FCD Interventions Elsewhere - The Collapse of the Lake Manchar Fishery

The potential for sudden changes at such crisis points is very well demonstrated by the impact of changes in the timing of the floods in the Indus River. Lake Manchar is the largest freshwater lake in Pakistan, and is recharged annually by water flowing from the River Indus through the Aral Manchar channel, upstream of the Kotri Barrage. The timings of the major floods at Kotri over the past 50 years have become progressively delayed, and are now over two months later. By the early 1960s the one month delay so disturbed synchronicity that the recruitment potential decreased below the value necessary to maintain the Lake fish populations. At this crisis point, the Manchar fishery collapsed to only 5% of its former value, affecting almost all fish species, and not just the Major Carps. It has never recovered (Cross D.1991b).

7.7 Expansion of a Thermodynamic Approach to the Whole of the Floodplain Fish Stocks

The relevance of the energetics approach, and of the validity of using MIKE11 hydraulic modelling results is now becoming more widely appreciated. It is clear that a more sophisticated model of the fish stocks as a whole is needed if the populations and species diversity of this remarkable resource are to be protected and preserved for the future. The following Section presents some initial indications of the range of variables which need to be considered in developing such a model, and of the implications of the findings of the Ecological Study for fish population management.

7.7.1 Classes of Fish to be Treated by a Recruitment Dynamics Model

- Longitudinal migrants (eg major carps), which release planktonic eggs at sites far upstream of the recruitment zone. The eggs and larvae are dispersed passively downstream across a floodplain during the flood period by the currents.

- Lateral migrants, which move actively across the floodplain from the river as the river overflows the banks, and release their eggs on site.

- Resident spawners, which live in the permanently flooded ponds and lakes on the floodplain, and spawn in these or over flooded land as available.

7.7.2 Major Variables

These classes of fish have different characteristics of breeding and recruitment:

- Longitudinal migrants;
- Fecundity - the eggs are released simultaneously in two day periods according to moon phase and external environmental stimulate. Dispersal of eggs is attenuated during transport downstream.
- Fertility - The broodstock may carry out several sequential spawnings, but later eggs are generally less viable than those released during the first spawning.
- Recruitment potential - depends on:
    - o the distance of the recruitment area downstream,
    - o the duration of transport,
    - o the amount of 'dilution' caused by spread of water into upstream flooded areas,
    - o the dispersion rate of water bearing eggs and larvae across the floodplain

(A) Lateral Migrants:

- Migration onto the floodplain coincides with overbank spillage, and spawning may occur immediately or at some externally-triggered time shortly after. Spawning may be limited to only a few hours on a single day.
- In either case, eggs are deposited almost simultaneously by the majority of the broodstock of a species, and spawning episodes by different species may also coincide.
- There is often no significant attenuation or passive dispersal of the eggs, since nesting behaviour and the deposition of sticky eggs on vegetation ensures that the eggs are not dispersed from the chosen spawning site.
- Sequential spawning may occur, usually at two or four week intervals (i.e. related to lunar periodicity). If so, then fertility is usually lower in later-released eggs. The volume of water entering the area is almost irrelevant. Stocks of fry may become density-limited if broodstocks are optimal, but this is less likely if they are depleted.

(B) Floodplain-resident fish species:

- These may spawn in permanent waters or on the floodplain. Breeding may occur over several weeks or even months, and is less likely to be simultaneous within a species.
- The eggs are non-dispersive - they are often guarded by the adults, or stuck to vegetation.

7.7.3 A Descriptive Model for Fisheries Management

Based on these facts, it is possible to construct a functional description in mathematical terms of the relative contributions of each type of stock to energy transfer to the rivers and to the seasonally flooded beels. This will include some appreciation of the role of secondary spawning (i.e a second spawning incident somewhat later in the year), and of the role of density-dependent factors as positive feedback mechanisms relevant to species survival strategies.

This model would be basically a conceptual model - i.e. its purpose is to reveal how changes in different variables are likely to affect patterns of recruitment potential and the eventual standing stocks of the three quite different groups of fish which together make up the fish community of the Bangladesh (and indeed, many other tropical) floodplains.

For rigorous analysis, some modifications of the methodology may be required - for example in partitioning energy flows between longitudinal- and lateral-migrating river fish stocks and floodplain-resident stocks in beels. In public health sectors, the interpretation needs to be expanded by field data collection, but in general the relationships between flood timings and extents are accepted as likely to be valid. The methodology is seen as providing far better indications of potential effects than have previously been available.

The energetic description of the floodplain fishery dynamics provides a good theoretical foundation for linking the aquatic and terrestrial environments. Local factors, such as the present stock densities and breeding success of the different stocks, will clearly influence the degree to which the postulated processes are actually affected by interventions. However, the facility to recognise and quantify the overlapping of critical events is seen as a major advance in the prediction of potential impacts of interventions on floodplain fish stocks and of those who depend on them.

The effect of reducing the attenuation of the populations of these tiny fish is very important when considering the potential effects of interventions. If they are present in the river water only for a couple of days, then the eventual yield from any part of the floodplain is highly dependent on how widely the flood waters are distributed about that area in that two day period. In simple terms, maintaining the floodplain fishery yields means that flood waters must be able to flush the plain repeated, ideally with a period of around two days, in order to obtain maximum recruitment.

Any provision which is aimed at maintaining recruitment - say a regulator or fish pass - should therefore allow as many of the larvae as normally reach the area before intervention to continue to do so. This is probably impossible using any feasible engineering solution which we can postulate at present.

The only easing of this constraint may lie in the possibility that in the unconfined floodplain individual planktonic eggs and larvae may in practice be exposed to several consecutive movements across different parts of the Jamuna floodplain as they mature. This presupposes that they only settle at a specific location when they reach the appropriate stage in their development at which they are able to move to the bottom and maintain their station against the currents. In such a case, a regulator which allows water into a storage cell of the floodplain may trap all the eggs and larvae contained in the water in the cell (always providing that it is operating on the critical two or three days during which eggs or larvae are present in the water), so that they all settle there, instead of many of them being washed downstream to a more appropriate location.

At present it seems reasonable to suppose that it should be possible to adapt the model as a more quantitative tool, allowing a somewhat more rigorous analysis of FAP impacts on fisheries than is possible at present. The magnitude of the resource presently in serious decline due to the lack of and rigorous ecological consideration and analysis indicates that action to develop a better understanding of the functional ecology of the fish stocks is a matter of the utmost priority. The delay in implementing the FAP17 Fisheries Study when such understanding is vital to the planning of much of the FAP-related work is therefore of considerable concern.

7.8 Summary of Fishery Recruitment Dynamics in Gaibandha Area

FCD projects have the potential to exert substantial impacts on the distribution of riverine fish species which are dependent on access to the floodplain during their breeding cycles. In this respect, the most important groups of fish are those species characteristic of the faster permanent rivers such as the Teesta, Dharla and Dudhkumar, (e.g. Oxygaster sp), and the major carps of the Jamuna, Teesta and Dudhkumar Rivers.

7.8.1 Main Patterns of Distribution of the Major Carps

These fish ascend the major rivers to spawn. They are present mainly in the Jamuna, but ascend the higher reaches of the Jamuna/Brahmaputra. It is uncertain as to whether the Dudhkumar River in Kurigram is also an important spawning river, with major carp ascending into Indian territory to release their eggs. A few are believed to ascend a short distance up the Dharla River, but they do not spawn in this river and there are no fry available in it. Major carp do not ascend the Ghagot River from the Jamuna to spawn, even when the Manos Regulator or breaches and public cuts may make this possible.

Formerly, they ascended into the upper Teesta River, but the construction of the Teesta Barrage has prevented upstream migration above this point, and they are now confined to the lower Teesta. However, the Bangladesh Water Development Board (BWDB) and the Dept of Fisheries (DoF) has recently started to stock fry of the major carps in the canals of the Teesta Project area, and this practice is likely to increase as the Project develops.

7.8.2 Fry Movements of the Major Carps

The main dispersal mechanism for the major carps is by passive transport as planktonic eggs and larvae. They are washed downstream from the spawning areas and across the floodplain, where they settle towards the bottom in shallow water with low current velocities and take station in their preferred environment.

Some older fish (15-25 days old - around 25mm long) may remain in eddies in the main rivers, mainly at the confluences of major rivers and tributaries, and swim actively to nearby semi-still waters on the floodplain as the opportunity arises. Such eddies cause natural concentrations of fry, and these are the preferred sites for commercial fry catching operations.

In Kurigram, fry from the Dudhkumar River may be carried laterally over the floodplain to beels in the Kurigram Project Area. In the Teesta Project Area, fry reach beels and the floodplain through breaches in the Teesta Right Embankment or through overbank spillage in the higher reaches, below the Teesta Barrage. There are very few major carp in the lower Gaibandha Project Area, and these

are mainly present as a result of deliberate stocking activities. Fry were formerly carried into the lower Ghagot River via the Manos Regulator, and probably still are, through the breach or public cut near the Regulator. So they occurred (and still do), in the lower Ghagot around Rasulpur. However, they are not common further upstream, nor are they found more than rarely in the Alai/ Old Bangali River system.

7.8.3 Spawning Activities of Minor Species

The minor carps (such as Oxygaster spp) form important local fishery in the Kurigram and Gaibandha areas. They are believed to prefer faster-flowing water, and appear from cursory field discussions with local fishermen to be very much more common in the Teesta and Dharla Rivers than in the Jamuna.

Fishermen reported that they release free-floating eggs in shallow water on the floodplain, but are capable of spawning over shallow sandbanks in the rivers if their access to the floodlands is impeded. It is reported that in the Pabna Project Area, these fish have been able to form viable populations in the beels, without having access to the main river. However, in the Gaibandha area at least, it appears that access to and from the Teesta may be of considerable importance to the stocks. The relative survival rates for eggs released in these two habitats are not known.

There is therefore a lateral migration onto the floodplain as the floods rise, and this is important for the supply of minor fish in the northern area. It is likely that Oxygaster from the Dudhkumar and the Dharla colonise beels and the floodplain in the Kurigram Project Area, whilst those from the Teesta and Dharla provide recruitment to Kurigram. The stocks in the Teesta and Ghagot restock the Teesta Project Area, Gaibandha Project Area, and much of the seasonal fisheries on the land between the Ghagot and Karatoya Rivers.

In the upper Teesta area, the abandoned Buri Teesta Project area is permanently restocked with major carps by the BWDB and DoF, but minor species also provides some recruitment over the floodplain. To the west of this part of the Region, between Thakuragaon and Dinajpur, there are no major river fisheries; instead, most of the fishery is derived from restocked culture fisheries. No data are available on the fish stocks and recruitment patterns in the upper Karotoya and Ichimati River floodplain.

At present there is still so little basic research that few hard guidelines based on sound knowledge can be given. This stresses the need for the continuation of the type of research which has been started through FAP 17. Nevertheless the basic principle for planning must be that to continue implementation of FCD projects that make no provisions for the likely biology and ecology requirements of minor species will likely prove to be reckless in both policy terms, as well as on social and economic grounds.

7.8.4 Implications

(A) Re-colonisation of the Upper Teesta by Major Carps

The stocking of major carps in the Teesta Project Area is presently confined to the major canals. When this system is completed, it will contain a potential reservoir of fish capable of breeding in the higher reaches of the Teesta.

The existing practice of restocking major carps in the Buri Teesta area has the potential to contribute to this process, provided that the benefits of allowing some mature fish to escape to the upper Teesta are recognised. The economic loss to the Buri Teesta fisheries which this would represent would be offset by the potential gains to other downstream fisheries.

(B) Recruitment of Major Carps from the Jamuna

Proposals to seal the Jamuna Right Bank will need to take account of the potential loss of access to the floodplain by the major carp fry, and for their movement into the river from those beels in which they may pass the dry season, in order to preserve the breeding stock and their potential value to the fisheries of the Gaibandha Project Area and, of course, downstream on both sides of the Jamuna River.

7.8.5 Summary

Impacts on Major Carp Stocks:

If major carp spawning in the Upper Teesta can be reestablished, this would renew the fry recruitment potential of the Teesta. This has major environmental implications:

- It would providing a positive impact to the Teesta Project itself, through the influx of planktonic eggs and larvae to the canals.
- It would provide a potential benefit to the Gaibandha Project Area if fry could be allowed access to the land inside the proposed Teesta Right Embankment.
- It would benefit floodplain fisheries downstream, since it would increase the stock of Jamuna fry available for floodplain colonisation and for collection for aquaculture.
- The existence of a number of breeding stocks in the Region should be seen as an important contribution towards fish stock security on the national scale.

There is no known spawning of major carps in the Ghagot and Karotoya system. Natural recruitment in the Gaibandha Project Area seems to be confined to fortuitous influx of fry from the Jamuna River through the Manos Regulator. This is only possible if the Regulator happens to be open and the flow is from the Jamuna into the Project Area at the time of the peaks of fry abundance.

Sealing the Jamuna Right Embankment without making provisions for major carp recruitment may reduce the overall spawning capacity of the national stocks by a very small amount. Whilst this might not be significant in isolation, the cumulative impacts of a number of interventions in which this effect is discounted as unimportant would nevertheless contribute to a severe negative overall impact nationally, particularly in view of the current and anticipated future pressures on this stock.

7.8.6 Mitigation

Facilities designed to facilitate the escape of breeding carps to the upper Teesta from the Buri Teesta and Teesta Project Areas could re-establish the capacity of the upper Teesta as a contribution to the national recruitment capability for the major carps. The settling lake at the head of the main canal of the Teesta Project, if it were operated and the fishing controlled appropriately, could be used to store these broodstock until the appropriate season, when they could be provided access to the upper river.

Either removing the Regulator, or ensuring that it is open at the appropriate times, will maximise the limited recruitment potential around Rasulpur, and will have a localised positive impact on major carp recruitment.

Structural modifications designed to promote controlled recruitment to the floodland may be feasible as a means of boosting floodplain production of these species. Co-operation with the Indian Government would almost certainly be a major requirement for this to be developed successfully, however.

7.8.7 Executive Action

Monitoring of the effectiveness of proposed migration facilitation structures suggested by FAP 3.1 will not provide data on their effectiveness or otherwise within the available timespan for the Gaibandha Project. Data on major carp migration passes should be sought immediately from Indian sources.

7.8.8 Impacts on Minor Fish Stocks

Minor fish are a vital component of the fishery in the northern sector of the Region. If research were to confirm their apparent confinement to the faster-flowing rivers and low frequency in the Jamuna, this would indicate a need to serve their special interests if the stocks are to be preserved. They need access from the Teesta, Ghagot, Dharla and Dudhkumar Rivers to the adjacent floodplain for effective spawning, and to return to these rivers at the fall of the floods. Proposals to seal the Teesta and Ghagot banks would therefore need to recognise the need for access in both directions of these fish. Their needs for specific types of structural access facilities may be different to those of the major carps - no data are available as guidelines at present:

- Sealing the Teesta right bank without adequate provision for recruitment to the floodplain will greatly reduce the recruitment of these fish, and severely reduce the availability of an important species for the local fishery. Similarly, confining the Ghagot would restrict access of minor species to areas to which it presently has access, and therefore will reduce catches.

- Although some can spawn in the rivers (notably the Teesta), if they are prevented from spawning on the floodplain then the river stock is likely to decline, and may even become extremely scarce over a longer period. Re-establishment of the Teesta stock from the Jamuna might be possible but extremely slow, because the fish are not common in the Jamuna.

7.8.9 Mitigation

Preliminary surveys suggest that currently stocks of Oxygaster spp. are locally more important in this area than in elsewhere in the North West. They need adequate access to and from the floodplain in the Gaibandha Project Area and the areas to the south and west of it. Two-way migration facilities are essential:

- in May-July for adult fish to move from the Teesta, Ghagot, Dharla and Dudhkumar into the temporary rivers and onto the floodplain, so that the natural spawning resource can be preserved;

- in October-November, for fry and adults to return to these rivers.

The possibility of using hatchery techniques to restock beels and pools in temporary rivers could provide protection to thesustainability of the stock, although its efficacy in supporting the existing supply to the poor is questionable.

7.8.10 Executive Action

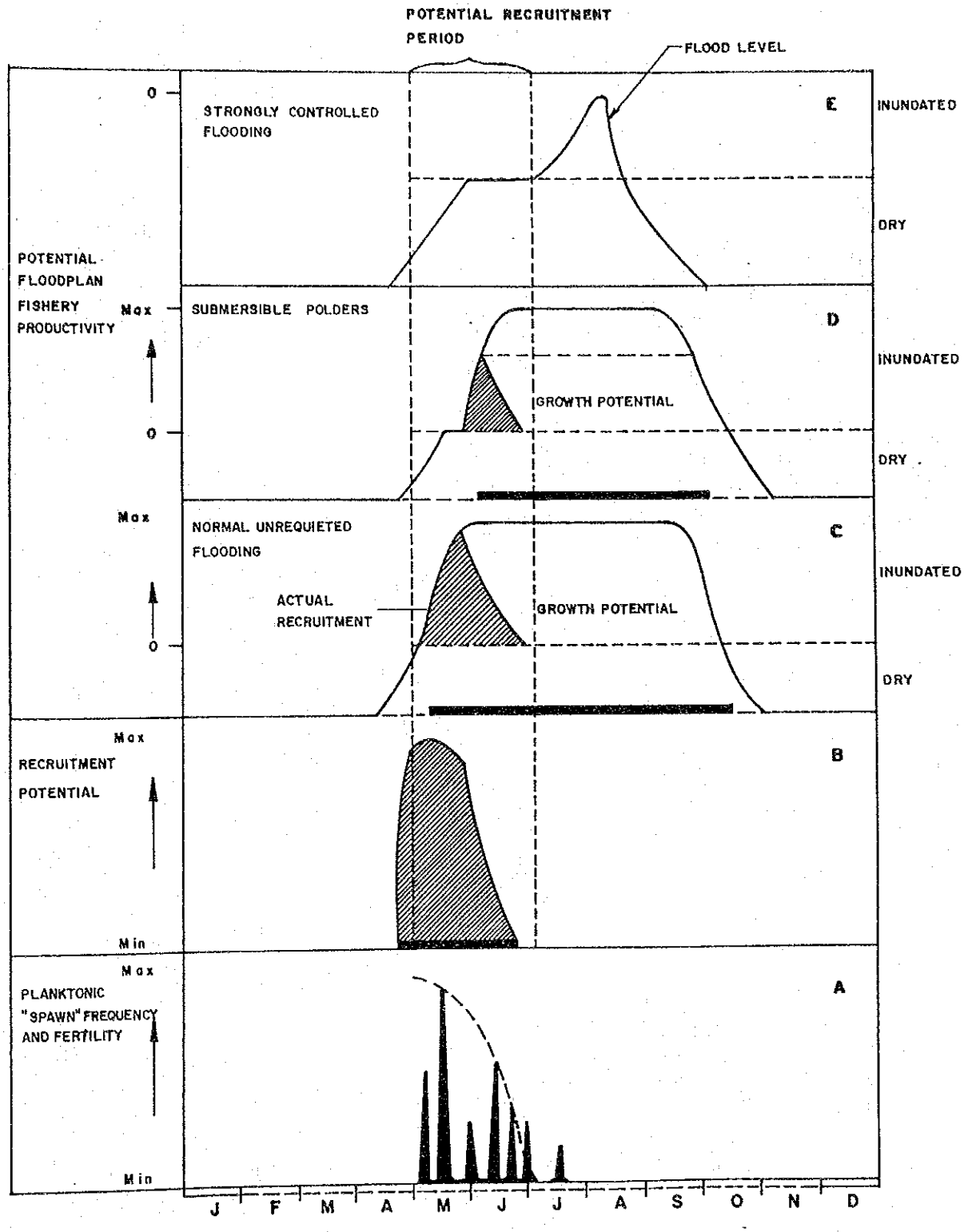
Investigation of the migratory requirements of minor species is urgently required, since appropriate management of, and possibly structural provisions for, water connections between the Teesta, Dudhkumar, Dharla and Ghagot and the floodplain are essential to protection of this important resource.

7.9 Second Degree Impacts

Severe negative impacts on all economically and genetically important species are to be avoided, even where this may involve a significant economic cost. The rapid spread of animal and plant parasites and diseases, and particularly of exotic diseases of fish, over the past two decades, represents a very significant threat to indigenous fish stocks worldwide. The preservation of diversity of commercial fish stocks must therefore be recognised as a primary objective in all regional development policy in the future if disastrous reductions in management options are to be avoided. This is particularly important when the stocks form a major part of the resources available to subsistence economies.

FIG - 7.1

POTENTIAL RECRUITMENT AND GROWTH OF FLOODPLAN FISH STOCKS UNDER NORMAL AND MODIFIED FLOOD REGIMES.



LEGEND

SPAWN FERTILITY

FREQUENCY

FIG - 7.2

POTENTIAL CHANGES IN FLOOD CHARACTERISTICS IN THE MIDDLE PUNGLI RIVER IF THE NORTHERN DHALESWARI INTAKE WERE CLOSED (NIKE II SIMULATION)