FINAL TECHNICAL REPORT

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TITLE OF PROJECT	The use of Sluice Gates for Stock Enhancement and Diversification of Livelihoods
PROGRAMME MANAGER / INSTITUTION	Saleemul Huq, International Institute for Environment and Development

	FROM	TO
REPORTING PERIOD	Sept 2002	Feb 2005

1 Executive Summary:

Project purpose: to optimise use of sluice gates to give improved integration of water control for natural fish stock enhancement with rice farming to benefit poor fishing and farming communities.

Research activities:

1. Determination of pattern of use and hydraulic characteristics of sluice gates in water management of compartments in consultation with local communities;
2. Investigation of existing use of fish and rate of fishing in communities inside and outside compartments around sluice gates, in relation to farming and other activities.
3. Participatory analysis of community views and expectations with regard to fish and farming leading to an understanding of their decision-making processes with regard to water control. Interactive consultations held with participating communities as the information was synthesised and the protocol developed.
4. Investigation of seasonal fish movements in the vicinity of sluice gates following a review of the interaction of fish swimming characteristics with the likely operation of sluice gates.
5. Synthesis of the water control needs of rice and fish given new data, with the communities, to arrive at an acceptable strategy and protocol for sluice gate management to increase livelihood options for natural enhancement of fisheries;
6. Creation of simple dissemination package.

Project outputs:

1. An optimal procedure and protocol for the operation of sluice gates and regulators to promote best integration of fish immigration and natural stock enhancement with rice farming in empoldered floodplains (to follow once final workshop has been held).
2. The understanding of the local social and institutional framework of fisheries, rice farming and water control to promote integration and co-management at the micro-level.
3. A synthesis of the information into a water management plan for uptake by the local participating communities and institutions.
4. A simple dissemination package for NGOs or government extension services to promote uptake of the protocol or synthesis on a wider basis

Contribution of the project towards DFID's development goals:

1. The participatory approach to research and involvement of local people in terms of obtaining information, providing feedback, modifying recommendations etc. made a major contribution to achieving the project goal. Use of participatory approaches raised awareness and empowered local people. It also ensured that dissemination occurred throughout the project.
2. Dissemination of research results at an Upazila level workshop resulted in an agreement to alter sluice gate operation. This will benefit poor fishers.
3. A good understanding of the local social and institutional context means that research is relevant and locally appropriate.
4. Dissemination of research results to policy and decision-makers at national, regional and local levels will affect water management policy and decision-making. Benefits will filter down to poor people. Some of this dissemination has already occurred, for example research results were published in a local Pabna newsletter (in local languages), and a three page project results brief was disseminated to over 100 key government and non-government national decision and policy makers in the area of water management, fisheries and agriculture.

2 Background:

The importance of the researchable constraint(s) that the project sought to address:
Most people living on floodplains in Bangladesh fish at some point in the year. At least 75% of the floodplain catch is taken by occasional or part-time fishers as a supplementary activity to rice farming. Over 40% of the Bangladesh floodplain has been modified and compartmentalised in order to give more complete control over water for rice growing upon which the country depends. In doing so, access to fish, which would normally contribute significantly to the resources available to poor people on the floodplains, is restricted. If the dynamics and timing of the discharge from sluice gates controlling water in the compartments in relation to migrant behaviour of the fish is understood, then a regime for the operation of the sluice gates for the mutual benefits of fish and rice can be devised. The natural stocks within the compartments will be enhanced. The options for the regime would be introduced to the local committee controlling the sluice gates who would also have been involved in the study and whose priorities and decision-making processes would also need to be understood and factored into the regime. Ultimately, the access of poor full-time and part-time fishers to fish on the floodplains will be increased and assured, with more commercial and nutritional options, whilst rice production will be unimpaired or even increased by 5-10% as indicated by successful rice/fish culture developments.

There is also a generic usefulness of the technical data that transcends the immediate social and institutional context and could contribute to development in other modified floodplains, e.g. the Mekong in Asia and the La Plata or Amazon in South America.

Summary of any significant research previously carried out:
Previously, the DFID Flood control Action Plan (FAP) Study 17, found that fish catches within fisheries compartments were significant although the catch consisted largely of small floodplain resident species ('black fish') and that the larger riverine species ('white fish') which previously had made up the bulk of the catch on unmodified floodplains, were largely absent. Tagging work has shown that white fish, which include the highly important major carps, can get through sluice gates and enter compartments although in small numbers. Inside the compartments most of the fishing is probably carried out on a part-time basis by farmers who augment their income and diet by optional fishing. Yields inside compartments can be greatly increased by enhancing the stock of white fish (major carps) artificially as shown by the results of the DFID/World Bank Third Fisheries Project. Introduction of large numbers of artificially reared fish is relatively costly. Proper management of sluice gates to allow white fish to enter in the typical seasonal pattern may enhance the stock inside a compartment naturally.

Every year, major carp and other white fish migrate upstream in large numbers to spawn in the early floods. They instinctively swim upstream and are positively attracted by fast moving water such as might issue from a sluice gate. The problem is the time when sluice gates are open and the speed of the current. There are threshold current speeds beyond which the fish cannot swim. Sluice gates are normally operated primarily for rice growing and are controlled by Sluice Gate Committees but, during the early floods, they may well be open to allow drainage of the compartment so integration with the natural enhancement of the fish stock is not incompatible with its use for rice culture. What is required is precise information on timing, discharge rates and other operational aspects to enable optimal usage. Much can be learned from reviews of the literature and experience of operating fish passes and fish-friendly structures. There is a further opportunity to increase natural enhancement of the fish stock. Both FAP 17 and CPP (Compartmentalisation Pilot Project) demonstrated that periodically through the flood, pulses of floating larvae and eggs drift downstream. If the upstream sluice gates are open, then fry will be swept into the compartment to supplement the intrinsic recruitment, again mainly with white fish. What is required is a detailed knowledge of when and how the sluice gates are operated in relation to rice farming and how this might be modified to take into account the seasonal movements and physical swimming capacity of fish. The CPP produced a hypothetical model of how this might operate with sluice gates.

The decision-making process over sluice gate operation is clearly critical and requires understanding at the community level. Equally, the existing farming/fishing activities of communities inside and outside compartments need to be understood in order to evaluate potential for change and the capacity for increased fishing as well as the impact of increased white fish production. In general, white fish are more marketable than black fish. Therefore, there could be a change in the ratio of fish consumed to those sold. The potential impact of changes in time allocation or catch value on community groups needs to be assessed.

How the demand for the project was identified:
The use of sluice gates in the community management of fisheries is one of the central features of the Government of Bangladesh/DFID/World Bank Fourth Fisheries Project, which is based on needs identified within the earlier flood control Action Plan – Fisheries (FAP 17), which highlighted this as a mitigating measure. This has now entered the National Water Management Plan of Bangladesh. The biodiversity conservation element is also enshrined in GEF Biodiversity Project. At all institutional levels, therefore, it is openly recognized that the role of water regulatory devices in relation to fish passage and stock enhancement needs to be properly understood. It will also give the fishers in the local community a voice within the local sluice gate committees.

3 Project Purpose:

Project purpose: to improve the decision-making capacity of poor farmers/fishers in managing the water in modified floodplains for the mutual and synergistic benefits of both rice and fish crops and, thereby, provide improved, more diverse and secure livelihoods.

The project addresses the identified development opportunity by providing information on how sluice gates should be operated to maximise floodplain fish stocks, directly into the hands of those that benefit from such enhancement and those that make policy and practical decisions on water management in Bangladesh at local, regional and national levels. Such knowledge includes information on when sluice gates should be opened and under what conditions (water turbulence, speed of water flow etc.) they should be opened to enhance floodplain fish stocks and hence local livelihoods.

4 Research Activities:

There were three main lines of action within the project.

1. Water management and hydraulic investigation.
The operation and performance of three sluice gates was examined and measured. The current velocities and discharge rates of each gate were measured in relation to extent of opening under present normal operating procedures during both letting water into and out of a compartment. The timing of operation of the gates and the exact purpose of each change over the annual cycle, in relation to rice growing, was monitored. These observations were then compared with the seasonal movements and known capabilities of fish to be attracted by and swim against outflow currents.

2. Fish and fishery observations.
Earlier reviews of discharge rates and their effects on fish in terms of measurable parameters were examined. Threshold velocity, critical velocity and attraction velocities were assessed in the context of the use of sluice gates and key fish species. This was then compared with actual values of discharge and other factors determined directly as outlined above. Regular samples and observations on the seasonal movements of the major fish species in the vicinity of active sluice gates were taken. The migration of adult 'white' fish upstream in the early floods as a behavioural response to sluice gate operation was assessed using catch monitoring, and mark-recapture techniques. This provided information on how to enhance recruitment of adult fish in the compartments with changes in sluice gate operation or design. Depletion monitoring experiments also measured how many fish failed to reach the sluice gate from the main river channel due to uncontrolled fishing activities.

3. Examination of fisher/farmer livelihood choices in relation to water management
The pattern of community use of fishing and rice growing inside and outside compartments was investigated using community-based participatory research approach. Dependency on fisheries and agriculture was assessed. The investigation asked how local people inside the compartment used fish and what impact increased returns might lead to. It also asked community views on how to improve sluice gate management, and water management more generally. Participatory approaches encouraged direct uptake of project results through local institutions. Most specifically, the operation of sluice gates is known to depend upon Sluice Gate Committees drawn from local users. Existing decision-making mechanisms related to sluice gate operation were investigated. Ways of optimising fishers' and farmers' livelihood options by appropriate modification of sluice gate management were assessed, and means of introducing the findings of the work into the decision-making process were investigated. Methods for this research included: rapid rural appraisal, household census, household survey, focus group discussions, open ended interviews, case studies, direct observations and workshops.

Research was conducted at three sluice gates in two locations in compartmentalised floodplains in Bangladesh. The research team included experts from three institutions: IIED, BCAS and MRAG Ltd. In some cases proposed research activities were modified. For example, depletion monitoring experiments were introduced following the recognition that fish recruitment to the floodplain might be severely affected by over fishing in channels leading to the sluice gate, as well as by sluice gate operation itself. All planned outputs were achieved.

5 Outputs:

Original outputs proposed:

1. A protocol for the operation of sluice gates and regulators to promote fish migration and natural stock enhancement with rice farming in compartments based on an understanding of the operation of different kinds of structures as their characteristics of discharge and current speeds, in relation to fish swimming capacity and response to currents.
2. An understanding of the economic and other roles of fish and fishing in the pattern of time-use and well-being of communities inside and outside compartments in the vicinity of sluice gates and an understanding of the decision-making mechanisms controlling the use of sluice gates. The possibilities of a community system for managing resources based around sluice gate management would be examined.
3. A synthesis of information on the use of sluice gates for water management to integrate rice culture with the needs for the enhancement of natural fish recruitment to provide a unified plan for water management, through the Sluice Gate Committees or other means, by the local communities. The improvement and impacts on livelihood options inside and outside compartments would also be clarified.
4. A simple dissemination package summarising the various pieces of information, with times and indicators, would be put together for introduction directly or through NGOs or DOF extension officers, to Sluice Gate Committees across the country.

All anticipated outputs were achieved. The protocol will be finalised once the final workshop has been held and feedback has been incorporated. Until then a 'project summary' has been drawn up.

Research results:

Please see Annex I.

6 Contribution of Outputs:

How project outputs have contributed towards DFID's development goals to date:

5. The participatory approach to research and involvement of local people in terms of obtaining information, providing feedback, modifying recommendations etc. made a major contribution to achieving the project goal. Use of participatory approaches raised awareness and empowered local people. It also ensured that dissemination occurred throughout the project.
6. Dissemination of research results at an Upazila level workshop resulted in an agreement to alter sluice gate operation. This will benefit poor fishers.
7. A good understanding of the local social and institutional context means that research is relevant and locally appropriate.
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Written reports produced to date:

- Literature Review, BCAS and IIED, September 2004
- Methodologies for Understanding Institutional, Economic and Social Aspects of Sluice Gate Management, BCAS and IIED, September 2003
- Fisheries Assessment and Data Collection Methodologies, MRAG Ltd, April 2003
- Final Sociological Report, BCAS and IIED, January 2005
- Fisheries Assessment Report, MRAG Ltd, January 2005
- Project Summary, IIED, BCAS and MRAG, January 2005
- Protocol for Sluice Gate Management, IIED, BCAS and MRAG, to follow

Future promotion pathways needed to maximise development benefit:

- National workshop delayed to April 2005.
- Dissemination of project reports to relevant stakeholders (electronic and hard versions) will occur in appropriate languages.
- Dissemination via websites will occur.
- Newspaper article(s) will be written and published.
- A feature in the Bangladesh Environment Newsletter (which reaches 14,000 people) will be published (in Bengali and English).
- Publishing research in peer reviewed scientific journal articles will occur.
- A proposal for a follow-on FMSP project dealing more with outreach dissemination of existing information is being developed.

ANNEX I: RESEARCH RESULTS

Fisheries and Hydrological Assessment

Magnitude and Timing of Migrations

Talimnagar Gate

During the first year of sampling (June-November 2003), about 5t of fish were caught trying to migrate into PIRDP through the Talimnagar sluice gate. These estimates exclude catches from seines, gillnets, traps and other gears whose orientation in relation to the gate is difficult to determine. Total catches including these gears were considerably greater with significant contributions from *Hilsa ilisha*.

Most (about 4t) of this fish catch was caught outside the sluice gate, constituting about 2t migrating passively towards the gate with the rising floodwaters and 2t actively migrating against the ebb as waters drained out of the scheme. The rest (about 1t) was caught inside the flood control scheme divided almost evenly between actively and passively migrating fish.

Active inward migrations against the outflowing water between October and November contributed marginally more (about 2.8t) to the overall catch of inwardly migrating fish compared with passive inward migrations (about 2.3t) caught during the flood period June-September.

During the second year, when sampling was restricted to a much shorter three month period (June-August), about 1t of fish were caught trying to migrate into PIRDP through the gate, most (600kg) of which were caught inside the gate. Most (about 800kg) were migrating passively with the flow of water into PIRDP.

Bawlakhola

Fishers at Bawlakhola aimed to take advantage of fish trying to migrate out of PRIDP rather than those trying to migrate in due to site-specific hydrological conditions. However, during the first year, just over 1t of inwardly migrating fish were caught inside PIRDP with three selected gears compared with nearly 3t of fish caught migrating out of the gate.

During the second year, 700kg of inwardly migrating fish were caught, again, almost all inside the gate.

Jugini

Fishers at Jugini focussed upon catching fish passively migrating into CPP with the rising floodwaters using nets set inside CPP facing towards the gate. During the first year only 300kg of inwardly migrating fish were caught compared to 500kg in the second year.

Overall, more fish migrated into than out of empoldered areas. The biomasses of passively and actively immigrating fish were approximately equal, but the numbers of fish (potential recruits) were not equal.

Species Compositions

Both passively and actively immigrating fish caught outside the sluice gates were mostly rheophilic whitefish species that typically migrate from the main channel to the floodplains to

spawn or feed and then return to the main river during the dry season to avoid the harsh environmental conditions in any remaining floodplain water bodies. These species included *Cirrhinus reba, Cirrhinus mrigala, Catla catla, Hilsa ilisha,* and *Labeo rohita*.

Passively immigrating fish caught by interceptory gears set inside the schemes during the flood season included whitefish and blackfish species. This suggests that passage into the scheme via the sluice gates is possible during this period. But whitefish were often conspicuously absent from catches inside the schemes during the ebb when fish must swim against the flow. This suggests that passage during the ebb flow may be more difficult or impossible for some species. This is consistent with findings from the mark-recapture study.

The proportion of passively immigrating whitefish species caught inside the gate increased significantly at Talimnagar during the second year of sampling when the gate was opened more frequently during the rising flood period.

At Jugini, where the gate remained opened and flow was only in an inward direction, a similar mix of species was caught both inside and outside the gate during both sampling years implying high inward passage success during this period.

Timing of Migrations

The timing of migrations through the sluice gate was assessed using daily catches recorded from liftnets, bagnets and jump traps. This did not take account of changes to fishing effort or gear catchability and therefore provides only an approximate indication of the relative strength of fish migrations with time.

At Talimnagar, catches were not recorded outside the gate until mid July when gears were set. Thereafter, catches increased rapidly, peaking in October as waters began to ebb. Catches inside the gate were recorded from June onwards with peak catches also recorded in October. At Bawlakhola, virtually no fish were caught outside during the rising water period because adverse hydrological conditions meant gears could not be set. Catches taken inside were highly variable with little discernable pattern. Catches at the Jugini gate varied and showed little discernable trend.

Differences in Recruitment Potential During the Flood and Ebb Periods.

Examination of length frequency distributions indicates that fish are significantly larger during the ebb compared to the early flood reflecting rapid growth between these periods. This implies that the passive migration phase is more significant in terms of potentially augmenting the number of recruits to fisheries inside the flood control scheme compared to the active phase.

For example, the mean weight of marbled gobies *Glossogbius giuris* during the early passive migration phase (July) is about 1g (corresponding to a 5cm fish) compared to 8g (for a 10 cm fish) during the active migration phase (October). One tonne of passively migrating fish caught during July would comprise nearly a million individuals, compared to 125,000 individuals during October. Thus, the numbers of fish migrating during the ebb may be 10 times more per unit biomass of fish, than that migrating during early flood season.

Reproductive Strategies of Migrating Fish

Monthly comparisons of the gonadosomatic index indicate that the species selected for sampling tend to spawn during the rising water period, around June or July. This compares well with results for the same and other species reported elsewhere.

Combining available estimates of length at maturity with length frequency data indicates that fish passively migrating into PIRDP via Talimnagar or Bawlakhola during the flood period are both immature and mature individuals. However, by the time water begins to flow out of the scheme, almost all the individuals of sampled species were sexually mature.

Passage Success and Factors Affecting Passage Success

The influence of a wide range of hydrological and sluice gate operational factors on passage success through the three sluice gates was examined. These included sluice gate aperture, current velocity, water pressure, turbulence and volumetric flow.

Passage success into the flood control schemes via the sluice gates varied from less than 5% to 100% at Talimnagar and Bawlakhola, but was consistently above 40% at Jugini where the sluice gates were open throughout the study.

Whilst passage success was positively correlated with sluice gate aperture at both Talimnagar and Bawlakhola, passage success was found to be significantly dependent upon only the flow of water entering the scheme (m^3s^{-1}) as measured inside the scheme. Passage success was found to increase linearly with increasing flow.

At Jugini, sluice gate aperture was not significant in determining passage success, but the aperture consistently exceeded $7m^2$ without considerable variability. It may be that beyond some threshold, sluice gate aperture becomes unimportant, and that other factors such as flow and turbulence become more important.

Passage success at Jugini was significantly dependent only on the turbulence of water measured outside CPP. Passage success increased as turbulence decreased. A similar but not significant trend was also found at Talimnagar.

Marked fish were released twice during the ebb flood at Talimnagar. The results indicate that whilst some fish released inside PIRDP were recaptured, none of those released outside PIRDP were recaptured within seven days and less than 5% were recaptured within three weeks of their release. This suggests that passage success is negligible during the ebb flood when the gates are often fully open and water flow outwards is very high. It is likely that fish cannot swim against the strong outward flow during this period.

Differences in species caught inside and outside the Talimnagar gate support this conclusion. Whilst similar species were caught inside and outside the gate during the rising water period, during the ebb, several whitefish species (that typically return to the main channel during the dry season) caught outside the gate were conspicuously absent from catches inside PIRDP. Similar species were also caught both inside and outside the Bawlakhola and Jugini gates during the rising water period.

Rheophilic whitefish species were more abundant during the first year of sampling compared to the second. This may reflect the greater frequency at which the gate was opened during the

first compared to the second year of sampling and/or differences in the duration of the sampling period.

Examination of the sampled size structure of migrating fish suggests that passage success is independent of fish size.

Institutional, Economic and Social Issues

The Economic Role of Fish and Fishing in the Community

The population of the two study sites is 6,850 in PIRDP and 2,986 in CPP. Village size varies between 943 and 2,060 people. 51.7 of the total population are male. The average household size is 5.7 in PIRDP villages and 5.5 in CPP villages. Both of these figures are larger than the national rural average household size of 4.9.

Respondents identified their own household wealth categories. In the two CPP study villages, 79% of households said they were poor or very poor. In the two PIRDP study villages, 55% of households said they were poor or very poor. Only 1% of households are rich in PIRDP, and only 6% are rich or very rich in CPP. One of the study villages in CPP (Kathua Jugini) has about 160 new families (38% of the total number of households) who migrated here from the Jamuna riverbank area after their land and properties were lost to bank erosion and floods.

The dominant natural capital asset of the villagers is land. Land holding size determines people's wealth and social status. An average of 54% of households in PIRDP study villages are effectively landless. This figure is 68% for CPP villages. Very few households own over 500 decimals of land in any study villages.

Standards of education are low in all study villages. In PIRDP, some 36% of household heads are illiterate and about 21% can only sign their name. However, education is improving, and better literacy levels mean that livelihood opportunities are increasing.

Many householders have multiple livelihoods. These provide income but also reduce household expenses or maintain family and socio-cultural needs. Livelihoods include agriculture (people who cultivate their own land, sharecrop in and out land, mortgage or lease in and out land, cultivate vegetables or work as a wage labourer on land), fishing (full-time, part-time or for subsistence purposes), wage labour, business, vehicle driving/pulling, professional skills, household work, service and other non-agricultural occupations.

Over the last few decades, agricultural productivity has increased as a result of high yield variety rice cultivation, the adoption of modern agricultural technologies, rural infrastructure development, marketing networks and other modern forms of communication. Irrigation is also common. Before sluice gate construction, the PIRDP beel area was underwater for seven to eight months a year and people cultivated a single rice crop (deep water aman paddy). Crop production was uncertain and floodwater often damaged the aman rice. These days, two or three crops are grown each year (including high yield rice varieties), and many different crop types are cultivated using irrigation. Onions are a particularly important cash crop. In CPP, vegetable cultivation has increased since sluice gate construction, but many other crops are no longer cultivated. High yield rice variety cultivation has increased, thus increasing food security. It is, however, harder to attribute changes in cropping patterns to sluice gate construction.

In PIRDP, the most common primary occupation of household heads is agriculture (at 48.9%) followed by fishing (at 17.5%). In CPP, the most common primary occupation of household heads is agriculture (at 21.8%), with only 7.7% having fishing as their primary occupation. In PIRDP, the most common secondary occupation of household heads is wage labour (30.4%), followed by fishing (29.4%). In CPP, agriculture is also the most common secondary occupation of household heads. Fishing is comparatively less important as secondary occupation.

Some 37% of households sampled in CPP rely on fishing to some degree, and 27% of these rely on fish for 80% to 100% of their family income. The remaining 73% only rely on fishing to provide 20% or less of their total family income. In PIRDP, about 27% of households rely on fishing to some degree for income, and of these, about 22% rely on fishing to provide 80% to 100% of household income.

In PIRDP and CPP villages, crop cultivators, service holders and those involved in business (as their primary household head occupation) have more valuable household assets than other occupational groups such as fishers, wage labourers, rickshaw pullers, household workers and carpenters. Poorer groups (mainly wage labourers, sharecroppers and small farmers) often engaged in fishing for both consumption and livelihood purposes.

Many people have shifted from their traditional livelihoods to new ones. In the past, people were primarily dependent on agriculture, business and fishing in the floodplain. More recently, people have become involved in business, pulling rickshaws, vegetable cultivation etc.

Seasonal variation is also observed, especially where rural livelihoods depend on agricultural activities. However, recent increases in irrigation mean that livelihood insecurity resulting from seasonal changes in demand for agricultural labour is reduced, as crops can be planted almost all year round. Diversification of livelihoods has also helped reduce seasonal vulnerability.

Recent construction of road networks has increased diversification opportunities, as has the installation of a power supply and other development initiatives. Local people felt that since sluice gate construction, income levels are generally higher and poverty has been reduced. Communications development, better marketing systems for agricultural goods, new employment opportunities at national and international levels, introduction of modern agricultural systems, and NGO programmes to eradicate poverty and enhance livelihoods have also all helped improve livelihoods.

Local people felt fishing had decreased in recent years, whereas livelihoods from farming, business, pulling rickshaws or vans, service provision and skilled labour had increased. Several professional fishers have migrated from villages in the PIRDP area to India, and subsistence fishing is almost redundant for most months in CPP. Many fishers have adopted alternative livelihoods such as pulling rickshaws or running small businesses.

Before sluice gate construction, fishers used larger meshed nets made from cotton thread. These days, fishers use nylon nets with a smaller mesh size. Some of these damage small fish. Dewatering (excavation of ponds and then pumping water out to collect fish) has also increased. This damages brood fish stocks and results in low fish production.

Where the primary occupation of the household head is agriculture or service holder, PIRDP households show the greatest increases in household assets since sluice gate construction (at 69%). Only 10% of these households claimed a decrease in household assets. The assets of households where the primary occupation of the household head is fishing show the largest reductions, except those of housework. In CCP, household assets have increased most where the primary occupation of the household head is business or 'other occupations'. Household assets have decreased most where the primary occupation of the household head is weaving or fishing.

Where the primary occupation of household heads is fishing, dependence on this one source of income tends to be higher than where household heads rely primarily on other livelihood sources. Fishers tend to be very dependent on fishing as their sole income source. This might make them more vulnerable than those who rely primarily on other occupations.

Rice and fish are traditionally the staple food for Bengali people, but households now consume less fish compared to the past. Fewer fish are caught in the open water, and if they can afford it, most people must therefore buy fish to eat from the market. Before sluice gate construction there was a shortage of rice, but this is no longer a problem. People also consume more meat and vegetables than previously.

The Social/Institutional Framework of Fisheries, Farming and Water Control

Sluice gate management committees exist at Talimnagar sluice gate in PIRDP and Jugini sluice gate in CPP. No committee exists at Bawlakhola sluice gate in PIRDP, where farmers send written applications to the Union Chairman, who forwards these to the Upazila Water Development Board office, which instructs the gate operator.

In PIRDP, fishers or farmers sometimes bribe or force the gate operator to open the sluice gate. Powerful local people also create pressure to operate the sluice gate. The gate operator does not always follow decisions made by the Upazila Nirbahi Officer (UNO) who chairs the sluice gate management committee, and who receives written applications for gate operation and chairs a meeting to make decisions on gate operation. A lack of coordination between committees also results in poor water management decision-making. Cooperation within the sluice gate management committee is inadequate and committee members do not supervise gate operation well. Some sluice gate management committee meetings are attended by few of the government committee members. Meetings are hard to get to for some committee members, and travel costs are considerable. Many committee members are overworked and cannot attend all meetings. The committee does not represent all relevant stakeholders, and only has one representative from the farming and one from the fishing community. The current fisher's representative has been absent for many months.

Bangladesh Water Development Board officials at Tangail usually instruct the Jugini sluice gate operator. Applications from, or consultation with the community on gate operation does not occur.

Many different formal and informal institutions operate in study villages. In CPP, an average of 60% of study village inhabitants were involved in at least one organization. Many households were involved in more than one. In addition, nearly all village households are involved with non-government organisations, which provide credit and savings facilities. About 93% of households received credit and some 7% of households were involved in

money saving schemes. Loans are used to construct houses, sink tube wells or raise household income from different livelihood activities.

Changing Sluice Gate Operations: Community Hopes and Suggestions

Local people felt that water management problems resulting from sluice gate operation included: gate operation according to farmers' needs, which reduces fish recruitment and disadvantages fishers; local elites influencing gate operation; individuals benefiting at the expense of farmers and fishers; faulty gates; farmers at different elevations having different water needs; crops in different seasons having different water needs; and local people in different areas having different water needs.

Local people felt that bottlenecks for improved sluice gate management included: poor cooperation within the sluice gate committee; poor coordination of government, community and other stakeholders; inadequate fisher representation on the committee; decision-making without field verification or monitoring; pressure groups influencing gate operation; inadequate gate operation guidelines; unavailability of government officials at key times; no supervision/monitoring of sluice gate management; low local awareness levels; and faulty sluice gate structures.

The most popular suggestion for increasing fish production without damaging rice production included opening the sluice gate during the first tide and early rising floodwater. Other suggestions included: law enforcement, particularly banning spawn and fish fry collection in rivers, dewatering and using fine mesh nets; a government programme releasing fingerlings in the beel; preventing fishing in certain months; banning certain fishing gear; establishing fish sanctuaries; re-excavating rivers, canals and beels to improve water flow and provide permanent water bodies; and controlling use of chemical pesticides and fertilizers.

Suggestions for future institutional involvement included: government implementation of suggested solutions; and involvement of different groups (government and non-government) in sluice gate issues.

Following a successful well-attended Upazila level workshop, the value of an annual general meeting near the sluice gate to discuss when the gate should be opened was recognised.

Additional suggestions by local government officials for improving water management and reducing poverty included: paying more attention to the needs of fishers in sluice gate management; paying less attention to the needs of fishers in sluice gate management; providing alternative livelihood opportunities for fishers if fishing becomes regulated seasonally; and improved direction and management of the sluice gate management committee.

Communities living outside the empoldered areas have suffered in recent years. These villages are significant in size, with about 18,000 people living outside CPP, and 12,000 in three villages outside CPP. This is more than three times as many people as those living inside the empoldered study areas. Fishers have suffered as perennial water bodies have become seasonal, and as traditional Hindu fishing practices, such as avoiding fishing in certain seasons, and using large mesh sizes also no longer occur. Sluice gate and embankment construction has increased sand deposition which means land is less fertile. It has also reduced rice and jute crop production due to flooding. Such flooding occurs when rising floodwater cannot enter the empoldered area, or when water is suddenly released from the

empoldered area. Historically floodwater used to disperse more rapidly into the wider floodplain, but now it stays for longer thus increasing crop damage. Non-scheduled sluice gate operation is also problematic. As is construction of infrastructure such as bridges and culverts, which may also impede water flow, and thus increase flooding. Currently all benefits accrue to those living inside the embankment. The fact that water cannot access the floodplain in the early flood period means that rivers are losing depth due to siltation. This then means that water overflows into nearby villages and fields. Suggestions for improved water management and poverty reduction include: giving people outside the empoldered area more say in sluice gate management; supervision by government and involvement of non-government organisations (for example with implementing development projects) and the army (for example with embankment construction); more regular opening of the sluice gate; new embankments and raised river banks to protect villages from flooding; river dredging and channel construction; plantations on river banks to reduce erosion; and repairing existing embankments and roads.

GUIDELINES FOR MANAGING SLUICE GATES

When to Operate Sluice Gates

Fish try to migrate into such flood control schemes throughout the year. Opportunities to improve recruitment therefore exist all year round, but improved management during the rising flood period compared to the falling ebb period is likely to bring the greatest benefit.

Research has shown that the numbers of fish attempting to migrate through sluice gates into flood control schemes during the early flood may, per unit biomass, be ten times greater than during the ebb.

Fish generally spawn in May-July before the ebb. To maximise recruitment, sluice gates should be operated so fish can enter schemes during the rising flood period before they spawn.

Few (if any) fish can penetrate sluice gates during ebb flow when outflowing current speeds exceed the maximum swimming speeds of most fish. During the early flood however, fish can passively migrate into schemes with in-flowing water and in some cases pass apparently unhindered through sluice gates.

How to Operate Sluice Gates

Research has also shown that during the rising flood period, sluice gates should be operated in such as manner as to:

- ***Maximise the flow of water (volume of water per unit time) into the flood control scheme during the rising flood period***. In effect, managers should try to maximise the transport of water (and therefore fish) through the gates.

- ***Maximise the frequency of gate openings***. Fish biodiversity and production benefits from more frequent gate openings, particularly during the rising flood period. Monitoring the catch rates of fishers landing both adult and juvenile fish in the main fish in the main channel may provide a good indication as to when the gates should be opened.

- ***Minimise the turbulence of water outside the gate***. Turbulence appears to obstruct the smooth passage of fish through the gate. Advice from hydrologists or engineers should be sought on how best to operate gates to minimise turbulence.

- ***Ensure that ebb flow velocities do not exceed the maximum sustainable swimming capacities of fish***. These velocities can be easily calculated from empirical formulae using estimates of the mean length and weight of sampled fish immigrating during the ebb flow period (see Fisheries Assessment and Data Collection Methodologies, MRAG Ltd, April 2003 for method calculation).

- ***Try to create ebb flows that attract the most fish to towards the sluice gate***. These optimal attraction velocities can be estimated for each species or group of species by plotting estimates of liftnet catch rates against corresponding water velocity sampled during the ebb flow period. Optimal velocities will correspond to the peak catch rates (see Fisheries Assessment and Data Collection Methodologies, MRAG Ltd, April 2003 for method calculation).

- ***Control fishing activities along channels connecting the gate to the main rivers***. With more than 50% of fish potentially being caught before they even reach the sluice gates in some cases, controlling fishing activities along channels connecting gates to main rivers may be equally, if not more, important than changing sluice gate operations.

Such interventions might offer a first step towards improving the recruitment of fish that is acceptable to farmers and other stakeholders who might be disadvantaged by increased flows of water into flood control schemes during the rising flood period.

Preventing fishing in channels connecting sluice gates during the early flood period should also benefit the local fishery. Activities during this period exploit sexually immature fish that are still growing rapidly. Reducing the effort during this period could potentially increase the size of spawning stocks thereby improving overall yield, as well as yield-per-recruit both inside and outside flood control schemes. Fishing activity in these channels might be permitted to resume during the ebb flood when (i) passage success through gates into flood control schemes appears insignificant, (ii) most fish have reached sexual maturity, (iii) and seasonal rates of growth have slowed.

Institutional, Economic and Social Issues

Recommendations	**Stakeholder responsible for implementing recommendation**
Recommendations for Improved Sluice Gate Management	
Sluice gate management committees should be established where they do not currently exist.	Bangladesh Water Development Board (BWDB), Local Government (Upazila Parishad)
Where sluice gates management committees exist, they need support to ensure they function effectively. Members need encouragement to ensure they actively undertake their responsibilities. This may involve providing funding to cover committee member and meeting costs. Such funds could come from government, which collects rent from leasing out *jalmohals* and from the water tax.	Ministry of Finance, Ministry of Land (MOL), Ministry of Water Resources and Department of Revenue
Sluice gate management committees may need training to help them function effectively.	BWDB, Department of Fisheries (DOF), Local Government and Engineering Department (LGED), Department of Agricultural

	Extension (DAE), non-government research organisations
Sluice gate management committees could benefit from more farmer and fisher representatives on them. This could include local people from outside the empoldered areas. The local community should elect such members. Farmer members should represent a range of different areas (and elevations) within (and outside) the flood control area.	BWDB, DAE, Upazila Parishad, LGED and Union Parishad
Each sluice gate management committee needs site-specific guidelines on gate operation. This should include information on gate maintenance and how to monitor gate operations. Guidelines should stipulate how regularly the sluice gate committee should meet, and provide site-specific technical information on aperture, current speed, recommended times of opening etc.	BWDB in consultation with others (including LGED and Union Parishad)
Sluice gate management committees should ensure sluice gates are opened early in the season to allow fish to migrate into the floodplain during the early flood season.	Sluice Gate Management Committees
Maintenance is necessary to ensure gates function effectively. This requires funding, which could come from the Water Tax (if enforced) or another source.	BWDB
The regular Upazila level monthly coordination meetings should incorporate sluice gate management as an agenda item, particularly before the early flood season.	Upazila level government officials
Sluice gate operation needs supervision by a sluice gate management committee member to ensure gates are operated according to agreed principles.	Sluice gate management committee
Recommendations for General Improvements in Water Management	
The Fish Act needs to be implemented/enforced. This includes preventing collection of fish spawn and hatchlings/fry, use of fine mesh nets, and de-watering (pumping out all water from beels/canals/rivers using low lift pumps to facilitate fishing).	DOF and the local Upazila level administration. Coordination may be needed with other Upazila level administration.
Further research on levels of inundation within the empoldered floodplain area may be required to understand which land (and who it belongs to) will be inundated first when flood water rises. This data could come from detailed Global Positioning System data, or from interviews with local people. Such data would facilitate a cost-benefit analysis for the entire empoldered floodplain, with a view to ensuring that possible losses of agricultural land are easily offset by gains from fish recruitment. It would also ensure fishers who benefit do not do so at the expense of the poorest farmers (who may rely on low lying land, which gets inundated first).	Research orientated non-government organisations, donors.
Establish fish sanctuaries in the beels and major rivers.	DOF and MOL
Existing sanctuaries may need re-excavation if they have become silted up.	BWDB and MOL
Fishing gear control: prevent use of *Bandh Jal* in channels connecting the river with the floodplain area. Such fishing gear stretches across the whole channel and catches large quantities of fish, thus preventing them from reaching floodplains.	DOF and Upazila level local administration. Coordination may be needed with other Upazila level administrations.
Stop hatchling collection in channels linking the floodplain with the river, in order to maximise fish recruitment in the floodplain. This may require consideration of alternative livelihoods for fishers relying on hatchling collection in channels.	DOF and local Upazila level local administration. Coordination may be needed with other Upazila level administrations.
Channels to sluice gates may need re-excavation (where siltation has occurred) to ensure water can flow freely to the floodplain.	BWDB
Hold an annual general meeting before the first floodwater comes. Involve local non-government organisations, fishers' societies and all interested local stakeholders in this.	Sluice gate committee/BWDB/Local government

NOTE: Four copies of the draft final technical report must be submitted to the Programme manager to be refereed. Once referee's comments have been incorporated, two copies of the finalised report should be sent to the Programme manager. Project Completion Reports and Final Technical Reports are also required by DFID in electronic format, for storing on the 'NARSIS' database. These should be submitted to the Programme Manager in either Word or Word Perfect formats. Where possible, portable display format (PDF) copies of the reports should also be submitted.