Management of Sluice Gate/ Regulators for Fish Stock Enhancement in Modified Floodplain Without Harm to Rice

 

By

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Synonyms and Acronyms

GDP	=	Gross Domestic Product
FCD	=	Flood Control and Drainage
FCDI	=	Flood Control, Drainage and Irrigation
FAP	=	Flood Action Plan
DFID	=	Department For International Development
FMSP	=	Fisheries Management Science Programme (DFID)
NRSP	=	Natural Resources Science Programme (DFID)
FGD	=	Focused Group Discussion
PIRDP	=	Pabna Integrated Rural Development Project
CPP	=	Compartmentalizaiton Pilot Project
CPUE	=	Catch Per Unit of Effort
MRAG	=	Marine Resources Assessment Group
IIED	=	International Institute for Environment and Development
BCAS	=	Bangladesh Centre for Advanced Studies
Beel	=	Deepest Area in a Floodplain
Haor	=	Depression in Floodplain
Bandh Jal	=	Liftnet (Bhesal) covering large area with partition or covering the entire width of a chennel.

CONTENTS

Management of Sluice Gate for Fish Stock Enhancement in Modified Floodplain Without Harm to Rice.

Background

Fisheries sector in Bangladesh plays a very vital role in the economy, employment generation and nutrition supply to the people. The sector contributes 5% to the GDP and, 6% for export earning of the country. Over 60% of animal protein supply in the diet of the people of Bangladesh is obtained from fish. About 10% of the population depend on fisheries and related activities for their livelihoods. About 70% of the rural people are involved in some sort of fishing in a year for additional income and for own consumption.

Being situated in the deltaic plain of the three major rivers – the Ganges, the Brahmaputra and the Meghna, Bangladesh is very rich inland open water fisheries resources in its rivers, canals, Haor and Beel (depression), reservoir and vast seasonal floodplain. Inland open water fisheries resources of Bangladesh is one of the richest in the world just after China and India. In the past the major source of the fish production in Bangladesh was the inland open water fisheries, which, even during 1960's, would contribute about 90% of the country's total fish catch. But due to various manmade and natural causes such as over fishing, FCD/FCDI projects, pollution, siltation of water bodies the fish production in the inland open waters has declined significantly and the biodiversity has been affected.

In the inland fish production system, floodplains play an important role. About two thirds of the country's land is flood prone and more than one third of the land remain under water every year for 4-6 months during rainy season. The floodplains rich in fish food and various nutrient, are excellent feeding, breeding and nursery ground of many of the fishes, shell fishes and other aquatic organisms and offer immense opportunity to the rural people for fishing for food and income. On the other hand, the flood would cause every year heavy damage to agriculture and property. The country faced serious problem of food storage. In order to meet the food deficiency for growing populations, Govt. launched green revolution during 1960s to grow more food. Under this programme Govt. took up flood control drainage and irrigation projects throughout the country. A total of 653 FCD/FDI projects with 13000 km embankment and 4190 sluice gates/ regulator have been implemented so far. About 5.5 million ha floodplains have been brought under the FCD/FCDI projects and about 1 million ha of area have been lost due to the FCDI programmes. As a result of the implementation of the FCD/FCDI projects, the farmers have been benefited. The farmers can now grow more than one crops in the FCDI project area where only one crop could be grown earlier. Rice production has increased significantly and the country has now become almost self sufficient in food grain production. On the other hand, the floodplain fisheries and in general the inland open water fisheries have been affected seriously due to the FCDI programme. Migration of fishes between floodplain and the river have been obstructed, water area has been reduced and degraded. Fish stock has declined in the floodplain and fish production has decreased. Biodiversity has been affected.

Poor Fishers' livelihood has been affected. Rural people have been deprived of having fish easily through subsistence catch. Fish consumption in rural households have decreased. Many professional fishers have migrated from floodplain area or have changed their occupation.

Various studies/research have indicated that fish catch and biodiversity have declined significantly within the FCDI floodplains area (Ahmed et al 1997, MPO; 1987, FAP-17, 1997, de-Graaf 1999, Halls 1999). Fish catch is 50% less in the project area than outside area.

Construction of fish pass and fish friendly sluice gates on experimental basis, has been found to enhance fish migration into the floodplain. By stocking of carp fries/fingerling in the floodplain fish catch has also been found to increase under the WB/DFID/UNDP Third Fisheries Project. But such operations are expensive and sustainability is uncertain. On the other hand through proper and timely operation/ management of existing sluice gates and regulators, the fish migration into the floodplain could be improved to a great extent for increased production of fish and biodiversity.

If the dynamics and timing of the discharge from sluice gates controlling water in empoldered / compartmentalized floodplain are understood, then the regime of operation of gates for mutual benefits of fish and rice could be developed. The natural fish stock in the floodplain could be enhanced by proper management of sluice gates to allow fish to enter in the typical seasonal pattern. But the information/ data on the dynamics of the discharge from sluice gates and the migration behavior of fish are not available in the country.

In order to acquire such information through research, and based on the outcome of the research to develop an optimal procedure and protocol for operation and management of sluice gates and regulators for fish stock enhancement in the floodplain through participation of different stakeholders (fishers, farmers etc), a DFID financed research project entitled “The Use of Sluice Gates for Stock Enhancement and Diversification of Livelihoods” was implemented in Bangladesh during the period from January 2003 to December 2004 in two FCD/FCDI projects namely, Pabna PIRDP in the Pabna District, and the CPP in the Tangail District by BCAS, IIED UK & MRAG etc. During the last two decades, a good number of FMSP and NRSP research project including this project under the DFID financial support have been implemented and a series of outputs about the management of inland fisheries resources for enhancement of fish production in Asian region including Bangladesh have been produced. In order to integrate the knowledge and outputs of these FMSP, NRSP and other projects into communications guidelines for dissemination to different stakeholders for floodplain fisheries management and enhancement, another DFID supported project entitled **“Promotion of FMSP guidelines for floodplain fisheries management and sluice gate control”** has been taken up for implementation during the period from April 2005 to October 2005.

This paper describes the results of the study project on The Use of Sluice Gate for Fish Stock Enhancement and Diversification on Livelihoods.

2. Objective of the project

The objective of the study was to develop a set of guidelines (Protocol) for sluice gate/regulator management and operation for the benefit of those dependent on rice farming and fishing in the modified floodplains of the country. The ultimate aim of the project was to manage water in the modified floodplain for mutual benefit of both rice and fish outputs and thereby to provide improved, more diverse and secured livelihoods of rural people including the poor.

3. Study Sites

In consultation with different key institutions and stakeholders and through review of literature and

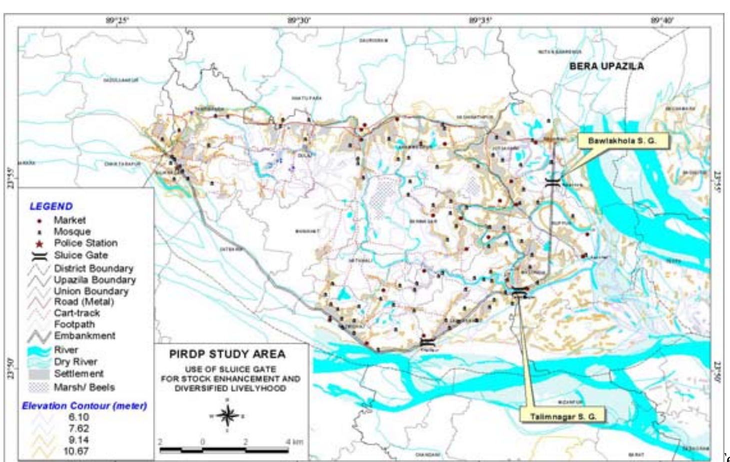
field observations the following two project sites with 3 regulators/sluice gates were selected for the study.
The following factors were also taken into consideration for selection of the study sites.

- Sluice gates are functioning
- Water flows in at least in one direction through the gate
- Connection to major river
- Typical gate sizes/designs (the case study gates at Tangail and Pabna are
- representative of about 78 % of sluice gates/regulators in general in Bangladesh).

FCDI Project with location	**Commend Area (ha)**	**Particulars of Sluice gates**			
		Name of Sluice Gates	**Connecting Rivers/Canals**	**Sluice Gate Type**	
Pabna Integrated Rural Development Project (PIRDP), Pabna District	27,400	1. Talimnagar	Badai River to the Jamuna	Six undershot gates	
		2. Bawlakhola	Natuabari Canal to Jamuna	Four undershot gates	
Compartmentalization Pilot Project (CPP), Tangail District	13,300	Jugni	Lohajang River to the Jamuna via Dhaleswari River	Three combined overshot and undershot gates and two outer gates operated as ‘fish friendly’ free surface vents.	

Project locations in Bangladesh

Jugini gate with CPP area



Talimnagar & Bawlakhola gate in PIRDP

4. Methodology

In order to achieve the objectives necessary data on fisheries, hydrology, institutional and socio-economic aspect were gathered through field observation during the period from January 2003 to October 2004.

A. Fisheries

(i) **Catch and Effort Monitoring:** Fish catch and effort of interceptory gear (gears whose setting with facing towards the sluice gate and opposite direction can indicate direction of movement of fish – Liftnet (Bhesal), set bag net, etc. were monitored around the sluice gate (inside and outside) in order to gather information/data on timing and direction of fish migration by species, estimate number and biomass of fish attempting to and succeeding in migrating through the sluice gate and to determine which species and gears are more impacted by the sluice gate and therefore which would benefit most from improved management and operation of sluice gate.

(ii) **Mark and Recapture Programme**: Fishes of different species marked with dye and released inside and outside of the gate were got returned from the fishers who recaptured those in their catch. This experiment was conducted to determine the passage success of fish passing through the gate and survival rate of different species in relation to different hydrological conditions such as current velocity, turbulence, and sluice gate aperture, and to generate relationships between velocity or turbulence and gear, catchability and to estimate total catch by using catch effort data.

(iii) **Length frequency data**: Length data of some important species were collected from the commercial catch to assess the age group for interpretation of migration pattern, rate of passage success by age and to determine the purpose of migration through the sluice gate.

(iv) **Reproductive state monitoring:** Fish gonads were monitored to determine the purpose of migration and period of spawning.

(v) **Depletion of fish catch prior to sluice gate passage:** Catch and effort monitoring was carried out in channel /river (Badhai river at Talimnagar Gate) connecting the main river and the sluice gate in order to determine the rate of capture of the fishes migrating into the flood control project area through sluice gate.

B. Hydrology and Sluice Gate Operation Monitoring: Monitoring of water depth, current velocity, turbulence, pressure, timing and mode of operation of sluice gate was carried out in the three sluice gates to develop hydrological basis.

C. Institutional and socioeconomic issues : Socioeconomic and institutional information were gathered through household survey/census, FGD, interview and observations in the two study sites in respect of changes in livelihood pattern and resources use, change in fishing and cropping pattern and intensity, conflicts over resources use, sluice gate operation, changes in socioeconomic condition of people etc.

5. Results and Findings

5.1 <u>Fisheries and Hydrological Assessment</u>

5.1.1 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.

5.1.2 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.

5.1.3 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.

5.1.4 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.

5.1.5 Reproductive State 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.

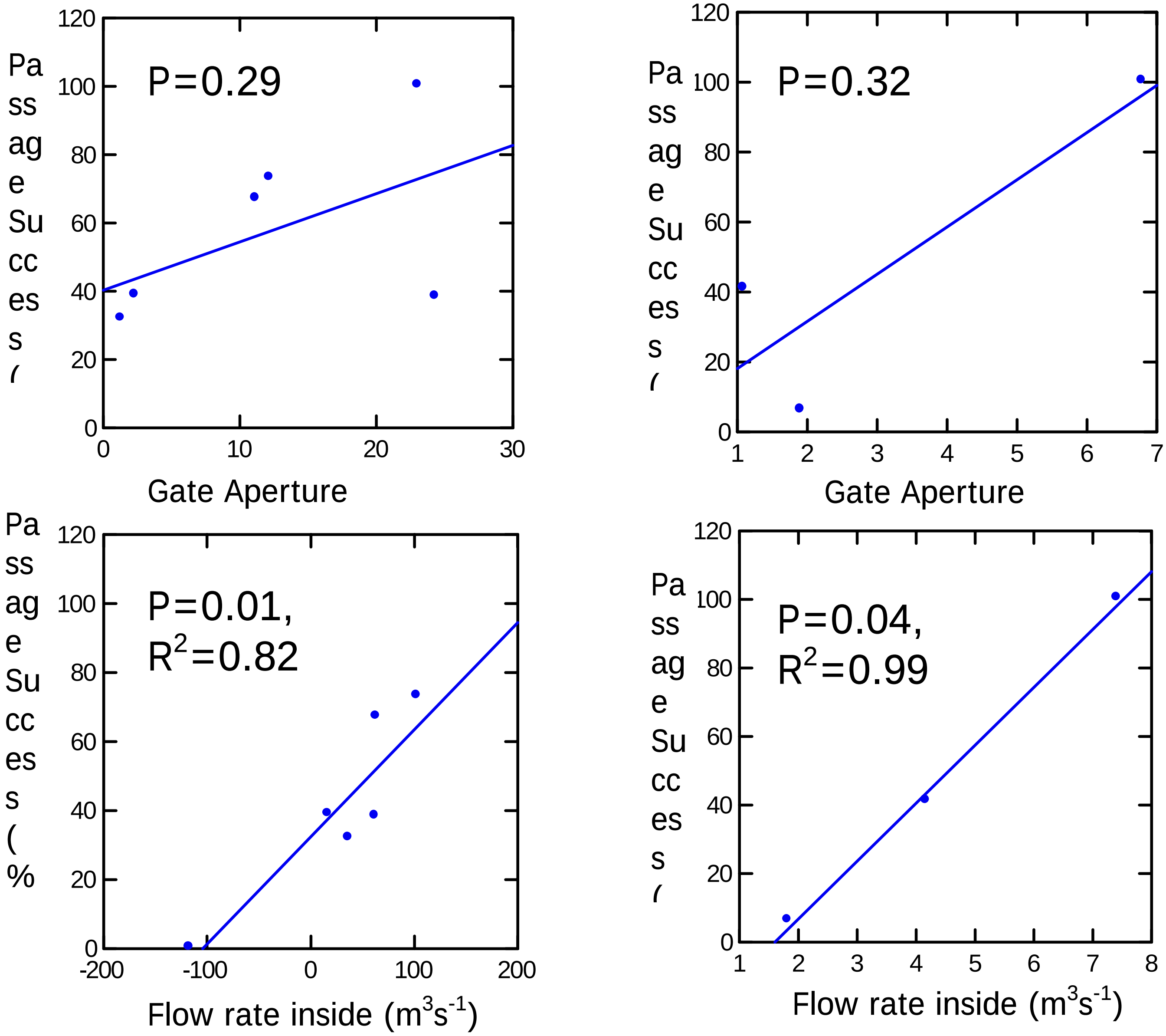
Combining available estimates of length at maturity with length frequency data indicates that fish passively migrating into PIRDP via Talimnagar or Bawlakhola during the flood period are both immature and mature individuals. However, by the time water begins to flow out of the scheme, almost all the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

5.1.6 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.

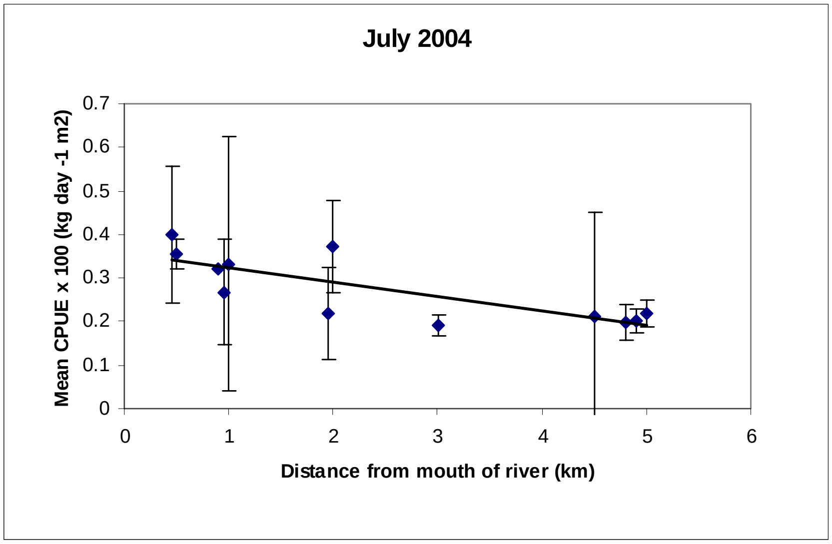
Differences in species caught inside and outside the Talimnagar gate support this conclusion. Whilst similar species were caught inside and outside the gate during the rising water period, during the ebb, several whitefish species (that typically return to the main channel during the dry season) caught 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.

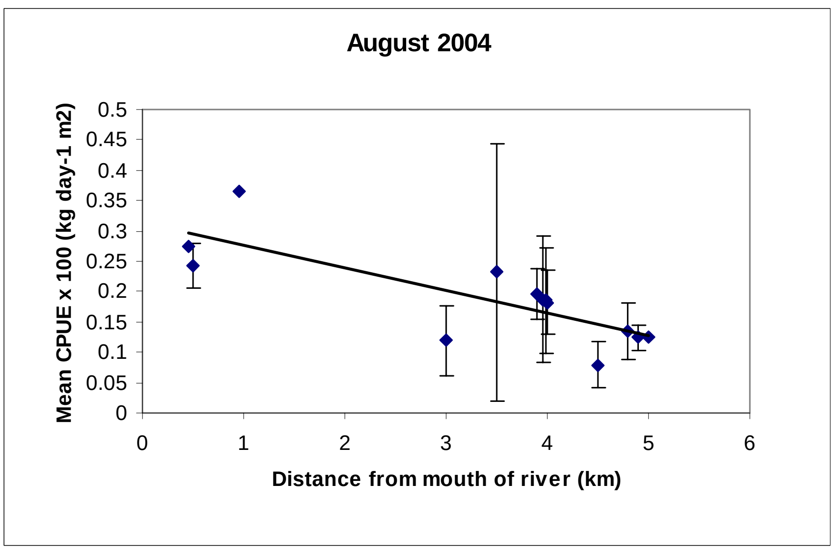
Rheophilic whitefish species were more abundant during the first year of sampling compared to the second. This may reflect the greater frequency at which the gate was opened during the first compared to the second year of sampling and/or differences in the duration of the sampling period.

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

5.1.7 Depletion of Catch rate prior to Sluice Gate passage

Catch and effort monitoring in the channel connecting the main river with sluice gate (Badhai river at Talimnagar) in PIRDP indicated that catch rate (CPUE) of passively migrating fish decreased positively with distance from the main river. It has been estimated that more than 50% migrating fishes were caught before they reached the sluice gate for migration. That means, had these fishes not been caught they might migrate into the floodplain area via sluice gate. Closing fishing or reducing fishing pressure in the connecting channel is equally important to opening the sluice gate in early flood period.





5.2 Institutional, Economic and Social Issues

5.2.1 The Economic Role of Fish and Fishing in the Community

The study shows that in CPP 79% of households were poor or very poor and in the PIRDP study area it was 55%. Only 1% of households in PIRDP, and only 6% households in CPP are rich or very rich.

An average of 54% of households in PIRDP and 68% households in CPP area are effectively landless. Very few households own over 500 decimals of land in any study villages.

Many householders have multiple livelihoods. 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, flood control measures and irrigation facilities. Before construction of embankment and sluice gates, the PIRDP low lying 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. Now, 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.

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.

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.

5.2.2 The 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. Lack of coordination among the members of the committee 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 from different hydrological area. Only one representative from the farming and one from the fishing community are included in the committee.

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.

5.2.3 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.

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. More than three times people as of those inside the empoldered live outside the polder area. Fishers outside have suffered as perennial water bodies have become seasonal. 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. All benefits now 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. Sluice gate management should look into the interest of the people leaving outside the modified floodplains.

6. Guidelines for Managing Sluice Gates

6.1 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.

6.2 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).

$$\text{Max Outflow Velocity} < U_{ms} = \frac{L\,(n\,(1.1\,(W)^{-0.14})}{100}$$

Where U_{ms} = maximum sustainable swimming speed, L = mean length of migrating fish, W = mean weight of migrating fish, n = constant = 3

- ***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.

7. Institutional, Economic and Social Issues

7.1 Recommendations for Improved Sluice Gate Management.

(1) Sluice gate management committees should be established where they do not currently exist.

(2) The existing sluice gate management committees 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.

(3) Sluice gate management committees may need training in proper management and operation of sluice gate to help them function effectively.

(4) Sluice gate management committees could benefit from more farmer and fisher representatives on them from a range of different areas (and elevations) within (and outside) the flood control area.

(5) Each sluice gate management committee needs site-specific guidelines on gate operation be developed for the committee. 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.

(6) 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.

(7) Maintenance is necessary to ensure gates function effectively. This requires funding, which could come from the Water Tax (if enforced) or any other source.

(8) The regular Upazila/ Union Parishad level monthly coordination meetings should incorporate sluice gate management as an agenda item, particularly before the early flood season.

(9) Sluice gate operation needs supervision by a sluice gate management committee member to ensure gates are operated according to agreed principles.

7.2 Recommendations for General Improvements of Fisheries and Water Management.

(1) The Fish Act needs to be implemented/enforced. This includes preventing collection of fish spawn and hatchlings/fry, use of fine mesh nets, and fishing by de-watering.

(2) Use of *Bandh Jal* in channels connecting the river with the floodplain area be prevented / con trolled. Such fishing gear stretches across the whole channel and catches large quantities of fish, thus preventing them from reaching floodplains.

(3) 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. The data could come from detailed Global Positioning System data,. 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).

(4) Fish sanctuaries be established in the beels and other water bodies of the modified floodplains. Silted up water bodies be re-excavated and sanctuaries may be established.

(5) Fishing including collection of hatchling in channels linking the floodplain with the river to be stopped to maximise fish recruitment in the floodplain. This may require consideration of alternative livelihoods for fishers relying on hatchling collection in channels.

(6) Channels to sluice gates may need re-excavation (where siltation has occurred) to ensure that water can flow freely to the floodplain.

(7) Annual general meeting may be held before the first floodwater comes. Involve local non-government organisations, fishers' societies and all interested local stakeholders in this.

(8) More research is needed on different FCD/FCDI project areas in different hydrological and geographical regions of the country. This will help develop a functional protocol for sluice gate in all environments.

8. Conclusion

1. Proper management and operation of sluice gates regulator would enhance benefits to both agriculture and fisheries in the modified floodplain and thereby the livelihoods of the rural people including the poor would be secured.

2. Improved technologies and management practices in both agriculture and fisheries would benefit both the sectors and the people.

3. Coordination among the different stakeholders at policy planning, implementation and target beneficiary level, particularly among the agencies responsible for development and management of water resources, agriculture and fisheries, is essential for overall sustainable

development.