Fisheries Dynamics of Modified Floodplains in Southern Asia

Sub-Project 3: Fish migration through flood control sluice gates

Project R5953

Fisheries Management Science Programme
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ODA FMSP Project R5953
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1. Background

The ODA Fisheries Management Science Programme's project R5953: Fisheries Dynamics in Modified Floodplains in Southern Asia was a three year comparative investigation of a hydrologically modified river floodplain in Bangladesh and a more pristine one in Indonesia. The project was designed to address two key developmental needs:

1. *To understand the implications of migration, reproduction and dry-season survival strategies of river fish on the management of inland capture fisheries.*

2. *To understand the impacts of flood control measures on the fish production potential of modified floodplains, and make recommendations on the wider management of floodplain resources for fish production.*

The second objective was investigated at the Bangladesh field study site, straddling the Pabna Irrigation and Rural Development Project (PIRDP). The study area in the south east of the PIRDP included two main sub-regions, inside and outside the main flood control embankment. In this area, the embankment is cut by three sluice gates: the main control gate on the Badai river at Talimnagar, and the two smaller gates to the north and south. The movement of fish between the 'in' and 'out' sub-regions was a central research priority of the overall project, and was studied in broad terms by the mark and recapture programme. This sub-project reinforced the monitoring of fish movements in the direct vicinity of two of the three sluice gates, which are the only routes by which fish can migrate in or out of the PIRDP scheme.

2. Sub-project objective

The objective of this sub-project was to determine the seasonality, directions and magnitude of fish migrations through flood control sluice gates at the Bangladesh PIRDP study site, for comparison with sluice gate operations and hydrological seasonality. Such information was required to make recommendations on the management of sluice gates for the joint benefit of both floodplain agriculture and fisheries.

3. Personnel

This sub-project was undertaken by the following staff of the Marine Resources Assessment Group Ltd (MRAG), 47 Prince's Gate, London, SW7 2QA, UK:

Dr Daniel D. Hoggarth, Fisheries Biologist, Project Leader,
Mr Kanailal Debnath, Bangladesh Team Leader
Mr Emdad Hossain, Research Assistant
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4. Research activities

This investigation was undertaken during the five months July to November 1996, in which the Pabna study site was inundated. Before and after this time, the flood control sluice gates were almost dry and the inside and outside parts of the study site were hydrologically disconnected. During the high water period, fish could potentially migrate through the sluice gates whenever they were opened, either passively or actively, depending on current strengths. At most times, however, migrating fish faced intense fishing pressure from several gears placed near the sluice gates to intercept their movements. This sub-project thus recorded the catches of such gears over the full five month flood season, as indicators of the migrations of fish in and out of the PIRDP flood control area.

Data were collected at two sluice gates: the largest 94.6m^2 aperture gate on the Badai river at Talimnagar, and the smaller 8.1m^2 gate on the Natuabari canal at Baulikhola, 8km northwards along the embankment (see Chapter 4, main report, for descriptions of the PIRDP flood control structures, management and geography).

For each sluice gate, daily recordings were made on the following information:

- *Hydrological Environment*

    1. Water height inside and outside the sluice gate.
    2. Sluice aperture (number of gates open, and their heights).
    3. Flow direction, including any leakage when gates closed.

- *Fishing Effort and Catches*

    1. Fishing effort and catch weights for each 'interceptory' gear in use in the vicinity of the sluice gate, subdivided by direction of fish movement.
    2. Species compositions of catches by gear type, subdivided by direction of movement and time of capture (day/night) where known.
    3. Length frequencies of catches of the two most abundant fish plus any 'key' fish species (*Anabas testudineus, Catla catla, Channa striatus, Glossogobius giurus, Puntius sophore* and *Wallago attu*) taken by each gear type, subdivided by direction of movement.

In general, catch/effort, catch composition and length frequency data were sampled as outlined in the project Survey Methodology (Appendix A). In this sub-project though, an almost complete census was taken of the fish catches at the sluice gates[1], using all the fishermen as respondents, to ensure that no seasonal catch peaks were missed by subsampling. Species compositions and length frequencies were subsampled as available.

As noted above, only the 'interceptory' gears used at the sluice gate were monitored. These were gears which were deliberately positioned to take advantage of the movements of fish towards or through the sluice gates, and whose orientation revealed the directional behaviour of the fish. The gears monitored were lift nets, *veshal* or *khora jal*; bag nets, *suti jal* and jumping traps, *urani*. Bag nets were suspended like a trawl in the strong current flowing downstream from the sluice gates. Jumping traps were suspended 0.1-0.5m above the water surface, adjacent to the sluice gates, to catch fish jumping from the strongly swirling currents created by the gates. Lift nets were positioned either upstream or downstream of the sluice gates: the nets monitored were all within a radius of 100m of the gates, in positions where the migrational behaviour of the captured fish could be confidently interpreted.

The directions in which fish were moving when caught were determined by joint consideration of the positions of the traps (inside or outside the embankment), and their orientation (facing towards or away from the sluice gate).

In addition to the above quantitative data, further information was sought on the social factors surrounding the sluice gates. The following information was collected by informal interviews during visits to the sluice gates:

- *Social Environment*

    1. Structure of ownership of fishing rights and leaseholding by gear type (eg. who decides when and where each gear is fished?).
    2. Management of the sluice gate (eg. who decides when to open the gate?, is there any illegal opening of the gate or wilful destruction or interference with its water-tightness?).

This social information is reported within the main project report (Chapter 4).

5. Outputs

5.1 Hydrology and Gate Operation

In 1996, the flood started earlier than usual on 23 March, but then rose only slowly to reach the 'bankfull' floodplain level of approximately 25ft above mean sea level (AMSL) at the end of June (see Figure 4.6, main report). Water levels outside the sluice gates eventually reached their maximum height in mid/late July, but continued to exceed the inside levels up until September 10. Potential water flow directions were thus inward up to 10 September, and then outward until water levels fell to the gate sills at the end of November.

Actual water flows depend, of course, on the opening of the gates. With only small amounts of local rain, and water needed for agriculture inside the flood control scheme, both the Talimnagar and Baulikhola sluices were partially opened for most of July, and fully opened for the first half of August, when the in/out head of water was minimal (Figure 4.6, main report). When enough water had been allowed inside for agricultural production (31-32ft AMSL), the gates were eventually closed in mid August to prevent further flooding. Though closed, some leakage was

[1] Some catches from jump nets at Talimnagar were missed due to the many gears in place, and no data were collected during 5 days absence from the field site in mid October.

observed at this time. As the outside floodwaters began to fall in mid September, the gates were partially opened to allow water out slowly, thereby prolonging the *aman* rice growth season. The gates were then fully opened half way through October, to allow the floodplains to drain.

5.2 Fishing activities and gear use

Fishing activity levels varied between the two sluice gates in line with their size and fishing opportunities. The large Talimnagar gate located on the 50m-wide Badai river had similar riverine conditions both upstream and downstream. The small Baulikhola gate, in contrast, was located on the narrow Natuabari canal surrounded by floodplain lands on both sides, with some small channels leading from the gate into the floodplain.

- *Lift Nets*

The Talimnagar sluice gate was fished in each month by up to two lift nets on each side (Table A3.1). At Baulikhola, up to six lift nets were positioned, but only on the inside of the gate, on small channels leading to and from the floodplain. No lift nets were positioned outside the Baulikhola gate, due to the unpredictable and occasionally strong lateral water flows at that position.

Except in the most gentle drift, lift nets can only be fished against the flow (ie with their open mouths facing the oncoming flow, holding the net down and open). In July and early August, when the gates were open and the waters flowed into the PIRDP, the lift nets were set inside and facing the gates to catch fish brought in with the current. In mid/late August, in contrast, when the gates were closed but still leaking, the lift nets were turned around to catch fish moving against the very gentle flows still coming through the gates from outside. When the ebb flows began in early/mid September, and the gates were opened, the Baulikhola and inside Talimnagar lift nets were then kept in the same position, to catch the emigrating fish. One of the lift nets outside the Talimnagar gate, however, was fished facing downstream at that time, but in a slack eddy on the side of the river where the water currents drifted upstream towards the sluice gate. Fish caught at this position and time were presumed to have been trying to migrate against the main water flows back up towards the sluice gate.

- *Jumping Traps*

Jumping traps were fished most abundantly above the swirling waters downstream of the Talimnagar sluice gate (Table A3.1). The Talimnagar gate, with its six 6.1m-wide gates, compared to only three 1.5m gates at Baulikhola, may simply present more fishing positions for jump nets attached to its extensive superstructure.

- *Bag Nets*

Only one suspended trawl bag net was fished at the smaller Baulikhola gate at the end of the ebb season. Fishermen reported that the Badai river at the Talimnagar gate was simply too wide and too strong to fish with a bag net. Even the small Baulikhola bag net was fished by a team of up to 15 fishermen in the strongest ebb flows due to the difficulty of hauling the net and landing the catches. Due to the large manpower requirement, the bag net was fished for the shortest possible time at the end of the season to reduce costs.

5.3 Seasonality, directions and species compositions of fish migrations

Based on the positions and orientations of the three sampled gear types, the daily catch data suggest four distinct migratory behaviours in the vicinity of the two sluice gates (Table A3.2, based on data in Figures A3.1, and A3.2). These migrations include both passive and active responses in both inward and outward directions, as described in turn in the following sections.

- *Early flood passive immigration*

The first catches taken by the lift nets during July and early August were of fish migrating passively inwards through the sluice gates with the incoming drift of flood water. This migration was comprised of mostly small floodplain fish species, including *Puntius sophore, Glossogobius giurus*, Chanda spp, *Gudusia chapra, Channa punctatus*, and mixed small shrimps (Figure A3.3).

- *Late flood active emigration*

From mid August to mid September, both sluice gates were closed on most days, but some water leaked in from outside due to the higher water levels outside the gates. Lift net fishermen inside the gates then turned their nets around and caught fish attempting to swim actively against the gentle flows, towards the gates in an outward direction. Such catches were particularly large at both sluices on the 24th of August (Figure A3.2), coinciding with an increase in water levels outside the sluices (Figure 4.6, main report). The outwardly moving fish included some species which had previously migrated inwards, *Chanda nama, Gudusia chapra, Glossogobius giurus*, and shrimps, and also some major carps *Catla catla* and *Labeo rohita* (Figure A3.3).

- *Early ebb active immigration*

In mid September, outside water levels fell rapidly, the sluice gates were opened, and water began flowing out from the PIRDP. During this early ebb season, fish were caught moving in both directions, but mostly inwards for the first month or so. This active immigration against the ebb was seen in catches of both the lift nets positioned in eddies at the edge of the Badai river, and in the jumping traps below both gates (Figure A3.1). The largest catches were taken in these gears as soon as each gate was partially opened.

In clear contrast to the earlier passive immigration, these catches towards the end of the flood season particularly comprised the major carps *Labeo rohita, Catla catla, Cirrhinus reba,* and *Labeo calbasu*, in addition to the predatory catfish *Wallago attu* (Figure A3.3).

- *Late ebb passive emigration*

The passive emigration of fish from the inside flood plains began as soon as the gates were opened, with small peak catches in both the Baulikhola and Talimnagar lift nets in mid September (Figure A3.2). A small number of fish caught in the jump traps at this time were also recognised by the fishermen as fish which had come from inside, due to their darker colour compared to the outside fish. In the early ebb, these emigrant catches were small compared to the active immigration of the major carps (Figure A3.2). As the waters fell though, the emigration continued after the immigration had stopped. Peak emigration catches of up to 450 and 240kg/day respectively in the Baulikhola bag net and lift nets were then taken on the 21st of October (Figure A3.2), coinciding with the drop in water levels below the floodplain altitude of 25ft (Figure 4.6, main report). After this peak, the emigration catches continued during November until the finally became dry at the end of the month.

This passive emigration was comprised of the widest range of species, including both small fish, especially *Puntius sophore*, and those major carps which had previously been caught migrating into the PIRDP only a month earlier (Figure A3.3).

5.4 Age compositions of fish migrations

The age compositions of the migrating fish were determined by studying the length frequencies of the fish catches at the sluice gates, compared with those sampled from other sites under the main research programme (see Section 5.7, main report).

For all species monitored, the vast majority of fish migrating were identified as the 0+ cohort, having been spawned at the beginning of the 1996 flood (Figures A3.4a-h). In general terms, such fish migrated inwards during the flood period and then outwards again during the ebb, though often with some overlap.

Some relatively large fish, probably 1+ year olds, were also found in the sluice gate catches. It is particularly interesting to study the movements of these older fish, as they generally represent the spawning stocks (see Section 5.9.1, main report). The movements of such fish may thus indicate where spawning takes place. Probable 1+ *Catla catla* were captured emigrating in August and immigrating in September (Figure A3.4b). A few 1+ *Channa striatus* were caught immigrating in August, while 0+ *C. striatus* were only found emigrating at the end of the flood season (Figure A3.4c). Both 0+ and 1+ *Glossogobius giurus* moved into the PIRDP in July and August and then out again with the ebb (Figure A3.4d). Large *G. giurus* seemed relatively highly inclined to migrate, with 11 of the 1,710 fish sampled at the sluice gates over 16cm (0.64%), compared with only 12 out of 5,028 during the same period in the main length frequency sampling programme (0.24%). Large *Puntius sophore* were also particularly captured moving in to the PIRDP in July and August along with the main 0+ cohort (Figure A3.4e). Only one 1+ *Wallago attu*, however, was caught in all the sluice gate samples (Figure A3.4f, Baulikhola lift net, August sample) compared to the many 0+ fish migrating. In comparison, 1+ and older *W. attu* were quite frequently captured in the main length frequency sampling programme in these months, particularly outside the embankment. The other non-'key' species sampled at the sluice gates were nearly all apparently 0+ fish, of less than 10cm in length (Figures A3.4g,h). Some larger *Channa punctatus* and *Cirrhinus reba* were caught, some of which may have been 1+ fish, in addition to one 44cm *Labeo rohita* captured in the Talimnagar jumping traps in October (Figure A3.4h).

In summary, the adult members of the smaller fish species *P. sophore* and *G. giurus* were found moving in to the PIRDP early in the season, but only accompanied by younger fish, suggesting they had already spawned outside. The larger *Catla catla* and *Labeo rohita*, in contrast, were not caught moving in with the young fish early in the season, but were caught moving against the ebb current just after high water suggesting they move upstream at this time.

5.5 Diurnal timing of fish migrations

Comparison of the species compositions of fish caught in daytime and nighttime samples showed that all the species migrated during both daytime and nighttime, except for the shrimp family group which was only rarely found in the daytime catches.

5.6 Magnitude of sluice gate fish catches and migrations

The size of the sluice gate fish catches depends on the relative sizes of the fish migrations and on how many of the migrating fish were actually caught. This in turn depends on the relative fishing effort levels during the different seasons, and the catchabilities of the different fishing gears. These factors are now considered along with the observed catches, in order to estimate the likely sizes of the different fish migration phases.

As may have been expected due to growth during the high water season, the largest sluice gate catch of 4,244kg was taken during the late ebb passive emigration phase (Table A3.3). Most of this catch was taken in the Baulikhola bag net, with the second largest catch coming from the Baulikhola lift nets at this time. Though the lift nets were positioned upstream of the bag net, the bag net may be assumed to have a particularly high catchability, staked across the full outflow of the sluice gate. As noted earlier, the Badai river at the Talimnagar sluice was simply too large and strong-flowing to fish with a bag net, or to fish efficiently with lift nets in the main currents, though lift nets were used at cross-river positions further upstream. Since the Talimnagar sluice drains a larger floodplain area than the Baulikhola sluice (Figure 1.1, main report) via the much wider Badai river, it may thus be reasonably assumed that many fish were able to escape from the PIRDP system through the Talimnagar gate during this season.

The first two flood phase catches were also larger at the small Baulikhola gate than at the main Talimnagar gate (Table A3.3). This may be partly explained by the slightly higher numbers of fishing gears at the smaller gate (Table A3.1), but it was also observed that the Talimnagar gears were fished in relatively inefficient positions at this time out of the strong main currents.

Only the early ebb active immigration phase produced larger catches at the Talimnagar gate than at the Baulikhola one, and from both the lift nets and jumping traps. It is, however, difficult to be sure how many of the fish caught in these gears could actually have been successful in migrating through the gates against the strong currents, or whether the fish were simply attracted by the swirling water motion. Since both gates were heavily exploited by the jumping traps at this time, it may at least be assumed that they produced catches more proportional to the actual fish abundances around the gates during this phase.

In summary, the above discussion suggests that the observed fish catches particularly underestimate the actual magnitudes of the two flood migration phases, and the final passive emigration phase at the Talimnagar sluice gate.

To estimate the actual magnitude of fish migrations into the PIRDP from the observed fish catches would require estimates of catchabilty coefficients for each gate/gear combination. In the absence of such figures, assuming that the Talimnagar migrations were at least as large as the Baulikhola ones, and that the different gears caught between 25 and 75% of the migrating fish, the sizes of the different migration phases may be estimated very roughly as shown in Table A3.4.

In the presence of the existing fishing operations and catches, the estimated migration sizes suggest that between 887 (ie 1,548 minus 661) and 3,995kg of small fish migrate into the PIRDP inside region during the early flood passive immigration phase, mostly through the Talimnagar gate. A further 282-2,565kg of fish, mostly major carps, may then migrate into the PIRDP during the early ebb active immigration phase, though it is less certain that such fish are actually able to get through the gates during the strong flows at this time.

6. Discussion and Conclusions

The fish migrations observed at the Talimnagar and Baulikhola sluice gates show that the behaviour of floodplain fish varies between species and may be significantly more complicated than a simple river-to-floodplain-to-river pattern.

The overall picture from this project is clearly a general trend of fish movements in to the PIRDP at the beginning of the flood, and out again at the end. Both small fish and a few major carps participated in both such movements, presumably to take advantage of the good feeding available on the floodplain during the flood. Adult fish of some small species were seen to migrate in to the PIRDP at the start of the season, but always accompanied by the newly

spawned juveniles, suggesting that they had already spawned outside before the PIRDP was connected with the outside waters. For other species, only the young of the year migrated in through the sluice gates, with the adult fish presumably remaining outside for the whole year. There was no evidence of fish migrating in through the sluice gates to spawn inside the PIRDP. Supporting this pattern, seine net fishermen just inside the sluice gates reported that they did not catch young carps until after the gates were opened.

In contrast to the general pattern, in the middle of the flood, many fish tried actively to emigrate from the PIRDP, when the waters were still flowing in, or to migrate inwards when the waters began flowing out again. Such behaviour is counterintuitive, as the first group of fish would be moving off the floodplain when good high water feeding was still available, while the second group of fish would be moving on to the floodplain towards the end of the flood season, placing themselves in danger of capture or dessication in the forthcoming dry season.

From a fishes point of view, the project study site may be rather confusing, with small rivers taking water in and out of the PIRDP scheme, to and from the larger main rivers outside. In this situation, the concepts of latitudinal (between river and floodplain) and longitudinal (up and down river) migrations (Welcomme, 1985) clearly depend on whether the main river or the secondary river is being referred to. With data on fish movements only available from this project at the two sluice gate locations, and no information available on the concurrent behaviour of fish in the main rivers, this analysis can only give a partial picture of the full behaviour patterns of these fish.

Assuming that migrating fish do not have a good mental map of the river environment to guide their movements, the observed migrations may be seen as simple responses by the fish to stimuli within their immediate vicinities. The late flood active emigrants and the early ebb active immigrants could then simply be swimming towards the currents coming from the sluice gates, thinking that they were heading upstream rather than on or off the floodplain. Such migratory behaviours are commonly found in river fish, taking fish upstream for spawning and fry release above the floodplain feeding grounds (Welcomme, 1985). Based on this spatially limited data set, it is thus suggested that the main passive on-off movements are latitudinal feeding migrations, while the active counter-current movements are both longitudinal spawning migrations, which may be ecologically beneficial elsewhere, but are probably inappropriate at these sluice gate locations.

The actual sizes of the fish migrations could not be accurately estimated due to the unknown efficiencies of the gears at the two sluice gates, with their complicated flow patterns and variable flow strengths. On simple but reasonable assumptions, it was estimated that the early flood passive immigration brought some 0.9 to 4 tonnes of newly spawned fish into the PIRDP, mainly through the large Talimnagar gate, compared to the 0.7t catches. These immigrant fish may form a significant contribution to the subsequent fish production inside the PIRDP over the subsequent season. However, since many of these fish were caught in lift nets further up the channels from the sluice gates, and the immigration comprised mainly fry rather than pre-spawning adults[2], these fish have only a limited potential for production (ie. from their own growth compared to the production of many more young fish). The sluice gate immigrations are thus unlikely to be the sole source of fish productivity inside the flood control scheme.

From a fisheries management point of view, it is recommended that flood control sluice gates should always be opened for as long as possible in the early flood season, whenever inside water levels are low enough to allow water into the PIRDP without threatening crop production or livelihoods. Encouraging restraints on fishing activities at sluice gates at this time would also have some potential for increasing inside production, though further constraints would also be

[2] In different years, when the flood rose more directly, more pre-spawning fish may be taken inside.

needed on lift net fishermen positioned above or below the sluice gates.

As confirmation of the importance of the sluice gates, it may be noted that in 1996 both gates were opened and inside fish productivity was higher than in 1995 (Section 5.2, main report). In 1995, the Baulikhola gate was frequently opened by fishermen, while the Talimnagar gate remained closed, under the careful control of the Water Development Board officer. As a result, 1995 fish catches inside the Baulikhola gate were significantly better than inside the Talimnagar gate, leading to much dissatisfaction among the Talimnagar fishing community.

7. Summary

- This sub-project investigated the seasonality, directions and magnitude of fish migrations through two flood control sluice gates at the Bangladesh PIRDP study site, in comparison with the hydrological season and sluice gate operations.

- Data were collected at the main Talimnagar sluice gate and the small Baulikhola sluice gate for the full 5-month flood season from July to November 1996. Daily records were taken of inside and outside water heights, sluice gate apertures and flow directions, along with the fishing efforts of three interceptory gears (lift nets, bag nets and jumping traps), and the weights, species compositions, length frequencies and directions of movements of their fish catches.

- In 1996, the flood started early on 23 March, but did not reach the floodplain height until much later at the end of June. Outside water levels then rose until mid/late July and gradually fell until the end of November.

- Due to the low water levels, the sluice gates were partly or fully open on all days up until mid August, thereby allowing water to pass into the PIRDP scheme. The gates were closed (though leaking) over the higher water period, and then opened again to allow water out from early/mid September.

- Fishing gear use varied between the two sluice gates depending mainly on their size. Lift nets and bag nets were fully utilised at the small Baulikhola gate, but not at the larger Talimnagar gate due to the strong River Badai currents. Jumping traps caught fish attracted towards the sluice gates by the outflowing water at the start of the ebb season, while the expensive bag net gear caught fish emigrating from the PIRDP at the end of the ebb. Lift nets were set in various positions on either side of the sluice gates to catch fish moving in both directions in different seasons.

- Migrating fish displayed four different migration phases, including both passive and active responses in both inward and outward directions. During the early flood, small fish, such as *Puntius sophore*, *Glossogobius giurus* and shrimps drifted in passively with the current. Towards the end of the flood season, when the gates were closed but leaking, some of the same species were then attracted towards the gates and moved back out of the system. During the early ebb season, the major carps *Labeo rohita, Catla catla, Cirrhinus reba,* and *Labeo calbasu*, in addition to the predatory catfish *Wallago attu* were attracted in to the PIRDP, while other small species migrated out. The largest migration, including virtually all the species previously recorded, was a passive drift out with the ebb, particularly coinciding with the final fall in water levels below the floodplain height.

- The vast majority of all migrating fish were the juvenile 0+ cohort, born at the beginning of the 1996 flood. Significant numbers of older *P. sophore* and *G. giurus* were also found moving in to the PIRDP early in the season, but only accompanied by the juvenile fish, suggesting they had already spawned outside. The larger *Catla catla*, *Labeo rohita*

and *Wallago attu* in contrast, were not caught moving in with the young fish early in the season, but a few of the larger major carps were caught moving against the ebb current just after high water suggesting that they move upstream at this time.

- The largest catches of migrating fish were taken during the late ebb passive emigrations at the small Baulikhola gate. Surprisingly, more fish were caught trying to migrate against the flows in to the PIRDP after high water, than passively at the beginning of the flood. Due to the difficulty of fishing the large Talimnagar gate, though, it was concluded that many fish both entered and escaped from the PIRDP waters through this route, without capture. The weight of young fish migrating in to the PIRDP during the early flood was roughly estimated between 0.9 and 4 tonnes, mostly through the Talimnagar gate, compared to the 0.6t catch from the existing fishing gears.

- To promote high catches inside the PIRDP, it is recommended that these flood control sluice gates should always be opened for as long as possible in the early flood season, whenever inside water levels are low enough to allow water into the PIRDP without threatening crop production or livelihoods. Encouraging restraints on fishing activities around sluice gates at this time also has potential for increasing productivity.

8. Acknowledgements

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Table A3.1 Fishing activities (maximum numbers of gear units observed) by sluice gate, position relative to the sluice gate, gear type and month.

Sluice Gate	Baulikhola (small)		Talimnagar (large)	
Gear Position	Inside gate	Outside gate	Inside gate	Outside gate
Lift Nets				
July	4		1	
August	5		2	1
September	6		2	2
October	5		1	2
November	1			1
Bag Nets				
October		1		
November		1		
Jumping Traps				
September		6		76
October		5		96

Table A3.2. Seasonal fish migration phases at the Talimnagar and Baulikhola sluice gates during the 1996 flood season.

Season	Migration Response	Migration Direction	Fishing Gears[1]	Gate Aperture
Early Flood July - mid Aug.	Passive	In	Out-facing LNs	Partly/fully open
Late Flood mid Aug. - mid Sep.	Active	Out	In-facing LNs	Closed, leaking
Early Ebb mid Sep. - mid Oct.	Active	In	Out-facing LNs in side eddies and JTs	Partly open
Late Ebb mid Oct. - Nov.	Passive	Out	In-facing LNs, BN and JTs	Partly/fully open

[1] LN=lift net, JT=jumping trap, BN=bag net.

Table A3.3 Total catches (kg) at the Baulikhola and Talimnagar sluice gates, subdivided by migration phase and gear type.

Sluice gate	Baulikhola (small)			Talimnagar (large)			Total catch (kg)
Migration Phase	Lift Nets	Jump Traps	Bag Nets	Lift Nets	Jump Traps	Bag Nets	
Early Flood Passive Immigration	582			79			661
Late Flood Active Emigration	371			76			446
Early Ebb Active Immigration	16	154		206	479		855
Late Ebb Passive Emigration	824	2	3307	71	41		4,244

Table A3.4 Estimated total weights of fish (kg) migrating through the Baulikhola and Talimnagar sluice gates, assuming exploitation rates of 25 and 75%.

Migration Phase	Weights Assuming 25% Exploitation Rate	Weights Assuming 75% Exploitation Rate
Early Flood Passive Immigration	4,656	1,548
Late Flood Active Emigration	2,968	987
Early Ebb Active Immigration	3,420	1,137
Late Ebb Passive Emigration	33,220	11,046

Figure A3.1 Daily catches per unit effort (kg/gear unit/hour) for the three interceptory gear types at the Baulikhola and Talimnagar sluice gates, for inwardly and outwardly-migrating fish (thin and thick lines respectively).

Figure A3.2 Total daily catches (kg) for the three interceptory gear types at the Baulikhola and Talimnagar sluice gates, for inwardly and outwardly-migrating fish (thin and thick lines respectively).

Figure A3.3 Total monthly catches (kg) at both Baulikhola and Talimnagar sluice gates, subdivided by direction of movement (inward, upper series, and outward, lower series) and species type (codes given in Table 5.1, main report) for those species comprising at least ½% of the total sluice gate catches.

Figure A3.4a Length frequencies of immigrant (upper series) and emigrant (lower series) *Anabas testudineus* sampled at the Baulikhola (Bau.) and Talimnagar (Tal.) sluice gates, from jumping traps (JT), lift nets (LN) and bag nets (BN), during July to November 1996. X-scale = 0-16cm fork lengths in half cm classes.

Figure A3.4b Length frequencies of immigrant (upper series) and emigrant (lower series) *Catla catla* sampled at the Baulikhola (Bau.) and Talimnagar (Tal.) sluice gates, from jumping traps (JT), lift nets (LN) and bag nets (BN), during July to November 1996. X-scale = 0-41cm fork lengths in 1cm classes.

Figure A3.4c Length frequencies of immigrant (upper series) and emigrant (lower series) *Channa striatus* sampled at the Baulikhola (Bau.) and Talimnagar (Tal.) sluice gates, from jumping traps (JT), lift nets (LN) and bag nets (BN), during July to November 1996. X-scale = 0-42cm fork lengths in 1cm classes.

Figure A3.4d Length frequencies of immigrant (upper series) and emigrant (lower series) *Glossogobius giurus* sampled at the Baulikhola (Bau.) and Talimnagar (Tal.) sluice gates, from jumping traps (JT), lift nets (LN) and bag nets (BN), during July to November 1996. X-scale = 0-28cm fork lengths in 1cm classes.

Figure A3.4e Length frequencies of immigrant (upper series) and emigrant (lower series) *Puntius sophore* sampled at the Baulikhola (Bau.) and Talimnagar (Tal.) sluice gates, from jumping traps (JT), lift nets (LN) and bag nets (BN), during July to November 1996. X-scale = 0-11cm fork lengths in half cm classes.

Figure A3.4f Length frequencies of immigrant (upper series) and emigrant (lower series) *Wallago attu* sampled at the Baulikhola (Bau.) and Talimnagar (Tal.) sluice gates, from jumping traps (JT), lift nets (LN) and bag nets (BN), during July to November 1996. X-scale = 0-54cm fork lengths in 1cm classes.

Figure A3.4g Length frequencies combined across gears and sluices for immigrant (upper series) and emigrant (lower series) *Ailia coila* (AC), *Botia dario* (BD), *Chanda nama* (CN), *Channa punctatus* (CP) and *Cirrhinus reba* (CR) during July to November 1996. X-scale = 0-45cm fork lengths in 1cm classes.

Figure A3.4h Length frequencies combined across gears and sluices for immigrant (upper series) and emigrant (lower series) *Chanda ranga* (CRA), *Gudusia chapra* (GC), *Labeo rohita* (LR), *Mugil cascasia* (MCA) and *Salmostoma bacaila* (SB) during July to November 1996. X-scale = 0 - 45cm in 1cm classes.