Fisheries Dynamics of Modified Floodplains in Southern Asia

Sub-Project 1: Fishing and Fish Survival in Dry Season Waterbodies

Project R5953

Fisheries Management Science Programme
managed by *MRAG*, under the ODA
Renewable Natural Resources Research Strategy

MRAG Ltd, March 1997

ODA FMSP Project R5953
Fisheries Dynamics of Modified Floodplains in Southern Asia

Sub-Project 1: Fishing and Fish Survival in Dry Season Waterbodies

Contents

1. Background
2. Sub-project objective
3. Personnel
4. Research activities and programme
   - 4.1 Census of dry season waterbodies
   - 4.2 Monitoring of dry season fishing
   - 4.3 Data Analysis
5. Outputs
   - 5.1 Census of dry season waterbodies
     - Numbers and areas of waterbodies
     - Dry season water retention
     - Fish catches
   - 5.2 Ownership, modification and management of dry season waterbodies
     - Ownership and leasing
     - Excavation
     - Use of fish attracting devices (FADs)
     - Fertilisation
     - Fish stocking
   - 5.3 Dry season fishing activities, gear use and catches
   - 5.4 Seasonality of dry season fish catches
   - 5.5 Escapement from dry season fishery
     - Absolute escapement
     - Proportional escapement
   - 5.6 Species Compositions of dry season fish catches
     - Numbers of fish species
     - Species compositions
   - 5.7 Age composition of dry season fish catches
6. Discussion and conclusions
7. Summary
8. Acknowledgements
9. References

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.*

In Bangladesh, these issues were investigated at 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 a flood control embankment. The annual production of fish inside the PIRDP is dependent on recruitment arising from either the entry of fish through the flood control sluice gates, or from the progeny of fish surviving inside the PIRDP over the dry season, when both fishing and natural mortality rates are at their highest. The entry of fish into the flood control scheme was studied under sub-project 3 (Fish migration through flood control sluice gates, Appendix E). This sub-project investigated the types of habitats used by fish to survive over the crucial dry season period.

This sub-project studied fish survival in dry season waterbodies, *in the presence of normal fishing activites*. For comparison, sub-project 2 (Density dependence of fish natural mortality rates, Appendix D) investigated dry season survival *in the absence of fishing*, by paying waterbody owners not to fish for the full dry season. In combination, these two sub-projects were broadly undertaken to show (1) where and whether fish currently survive over the dry season in floodplain waterbodies, (2) the relative importance of fishing and natural factors on dry season survival, and (3) whether any waterbody types could be used as dry season reserves to increase fish production.

2. Sub-project objective

The objective of this sub-project was to quantify the availability of different types of dry season waterbodies inside and outside the Bangladesh Pabna study site, and their relative importance for both fish survival and fish catches.

3. Personnel

This sub-project was undertaken by the following collaborating 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

and of the Bangladesh Agricultural University, Mymensingh:

Mr Ranjan Kumar Dam, M.Sc. Research Student

4. Research activities and programme

This sub-project was undertaken over the 1995/96 dry season from the start of the *kua* and *katha* fishing seasons in November 1995, until the end of the dry season in May 1996. The field research programme involved two main stages, firstly to quantify the relative amounts of different types of dry season habitats, and secondly to record detailed information on a randomly selected sub-sample of the waterbodies of each type.

4.1 Census of dry season waterbodies

The relative numbers and importance of different types of dry season waterbodies were determined by interviewing communities and households in the Pabna study site, both inside and outside the flood control embankment, about the waterbodies in their vicinity. In this sub-project, the 'inside' region included the 'adjacent' region, as defined for the project's routine catch effort sampling (see Chapter 3, Figure 3.6, main report). Group interviews were undertaken at the 20 catch/effort sampling villages, 10 inside and 10 outside the FCDI scheme (see Figure 3.6, Chapter 3, main report).

Initial interviews distinguished 5 types of dry season waterbodies:

Beels	Perennially flooded lakes, usually too large to dewater
Rivers	Perennially flooded rivers, usually too large to dewater
River *Kuas*	Deep sections in rivers/canals, which may be fished by dewatering
Floodplain *Kuas*	Floodplain depressions/ponds, which may be fished by dewatering
Household *Kuas*	Household '*mathel*' ponds, usually created during the excavation of earth to raise the land height for housebuilding.

'*Pukur*' culture ponds, permanently separated from the floodplain environment by their large embankments, were not included in the survey as these usually do not interact with the natural fish production on the floodplain.

For the large *beel*, river and river *kua* waterbodies, a complete census was recorded of all the waterbodies in the inside and outside regions. For the smaller, more common floodplain and household *kua*, the numbers of waterbodies were estimated by subsampling. Numbers of floodplain kua were estimated from the numbers in the vicinity of the 20 catch/effort sampling villages. Numbers of household kua were estimated from those owned by a randomly selected 10% sub-sample of households in the 20 villages, as recorded on district family taxation lists. Sampled data were raised to estimate the total numbers and areas of waterbodies on the floodplain, using the total number of villages in the inside and outside sampling regions, and the village population sizes from the taxation lists.

For each waterbody in the survey, the following information was recorded for analysis:

- Name of waterbody (if named)
- Name of owner
- Lease arrangements by gear type (lease durations, costs, regulations if any)
- Location (name of nearest village, project location code)
- Waterbody type (perennial *beel* (with *katha*), perennial river/canal section (with *katha*), canal/river *kua*, floodplain/*beel kua*, household *mathel kua*)
- Excavation (unexcavated, completely excavated, enlarged/deepened by excavation)
- Size (area at start of dry season, excavated area, expected date of drying out *or* estimated average minimum dry season depth if perennial)
- Fish attracting devices (tree branches, bamboo, water hyacinth, others?)
- Fertilisation/feeding (fertiliser/food type, frequency of addition)
- Fish stocking activities (species, number/weight of fish added, dates stocked)

Fishing activities (gear types used, expected number of fishings by each gear type per year, expected average catch of main species from each gear type per year)

4.2 Monitoring of dry season fishing

Following the waterbody census, a sub-sample of waterbodies was randomly selected for detailed study of fishing activities and catches. The sample included two *beel* waterbodies and three of each other type of waterbody in each region, making a total of 28 waterbodies in the monitoring study.

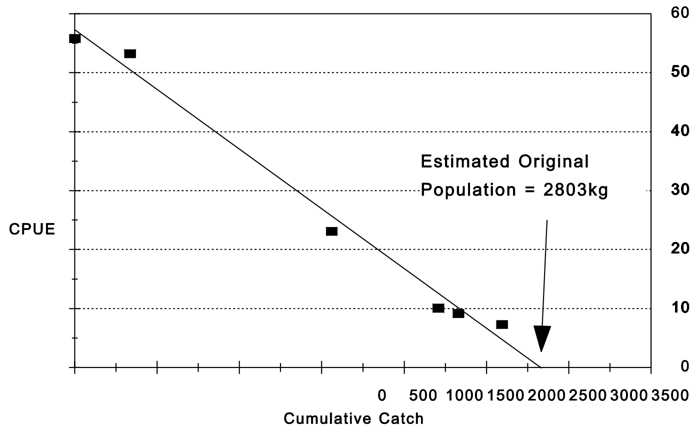
For the smaller floodplain, river and household *kua* waterbodies (coded FKU, RKU and HKU respectively), total fishing efforts and catch weights were recorded for each gear type in use, in each and every half-month period over the dry season. This information was collected using recall interviews with the waterbody owners and fishers to give a complete census of fishing activities. For the larger *beel* (B) and river (R) waterbodies, it was impractical to record fish catches from the smaller fishing gears due to the variable numbers of fishermen using these gears over the season. Complete censuses were, however, taken of the *katha* brushpile traps and *kua* dewatering used by the waterbody owners to take the majority of the dry season catches (78% of the catches in both the inside and outside regions from December 1995 to May 1996 were taken by these gears, as estimated by project catch data).

Catch compositions and length frequency samples of key species were also taken from the monitored waterbodies using the standard approaches given in the Survey Methodology document (Appendix A). Length frequency samples were taken in January, March and May 1996, in the same months as the main sampling programme, to aid comparison.

4.3 Data Analysis

In general, the census and monitoring programme data were simply analysed to compare the different waterbody types, within the two study regions, to determine their relative contributions to the inside and outside dry season fisheries. The characteristics compared between waterbody types and regions included the relative numbers and areas of each type of waterbody, their minimum dry season depths or dates of dessication, and the seasonality of their fish catches, gear compositions, species compositions, and fish length compositions.

An important part of this sub-project was to determine the escapement of fish in dry season waterbodies. 'Escapement' is used here to mean the weight of fish which was *not caught* over the dry season, and thus remained to contribute to the spawning activities and recruitment for the next flood season. Such escapement was calculated from the monthly catch and effort data in each monitored waterbody using the 'Leslie' depletion model (Seber, 1982). In the simplest terms, the Leslie method is a plot of fish abundance, as indicated by catch-per-unit-effort (CPUE) data, against the cumulative catch. As indicated below, a regression line through the data points would intersect the x-axis when CPUE fell to zero, ie. when all the fish had been caught. In a regression of CPUE against the cumulative catch, the original population at the start of the dry season may thus be estimated as the intercept on the x-axis (ie. the y-axis intercept divided by the slope). The escapement may then be roughly calculated as the original population minus the actual catch taken, assuming zero natural mortality and no emigration from the waterbody during the dry season.



This Leslie method of estimating escapement was applied to those waterbodies which did not dry out during the 1996 dry season, and were not dewatered for '*kua*' fishing. Several of the monitored waterbodies were dewatered towards the end of the 1996 dry season, sometimes after being depleted using *katha* or other gears: all such waterbodies were assumed to have been completely 'fished out'. The Leslie method was applied to catch data summarised on a monthly basis. When waterbodies were fished with more than one gear type, the cumulative catch was taken as the total from all gear types, and the CPUEs from individual gear types were used as the indices of abundance.

5. Outputs

5.1 Census of dry season waterbodies

- *Numbers and areas of waterbodies*

In both the inside and outside regions, the perennial *beels* and river sections[1] were the largest in size, usually several hectares (Table A1.1). The dewaterable floodplain and river *kuas* were smaller, usually less than one hectare, and the household *kuas* were generally very small, with average dimensions of around 12.5 by 6 metres. Numbers of waterbodies, however, followed the opposite trend, with very few *beel*s and river sections, hundreds of floodplain and river *kuas* and thousands of household *kuas* (Table A1.1).

Combining the numbers and sizes of waterbodies, the dry season total areas of the *beel*s, rivers and household *kuas* then become similar, generally an order of magnitude larger than the floodplain and river *kuas* (Table A1.1).

Comparing across the FCDI embankment, the inside region had a greater area of *beel*, floodplain and river *kua* waters, while the outside region had more river waters and household *kua*s. The five waterbody types were, however, all well represented in both regions.

- *Dry season water retention*

Water is retained throughout the dry season in most *beel* and river waterbodies in both the inside and outside regions (Table A1.2). In contrast, and reflecting their sizes, up to 50% of floodplain and river *kuas* retain some water through the dry season, while only 13-15% of the

[1] Rivers were surveyed in approximately 1.2km sections as defined 'location codes', see Chapter 3, Figure 3.1.

small household *kuas* do not dry out. Minimum water depths and dates of dessication follow the same trends, with *beels* and rivers retaining 0.5-2.4 metres of water, floodplain and river *kuas* retaining 0.7-1.0 metre of water or drying out by March, and household *kuas* mostly drying out by January (Table A1.2).

- *Fish catches*

Total fish catches, as reported by census interviewees, are roughly proportional to the sizes of waterbodies, in both the inside and outside regions (Figure A1.1b). The largest catches are generally taken from the beel and river waters, and the smallest ones from household *kuas* (Figure A1.1a). Reflecting this pattern, the greatest catches are mostly taken from the deeper perennial waterbodies (Figure A1.1e).

5.2 Ownership, modification and management of dry season waterbodies

- *Ownership and leasing*

Floodplain, river and household *kua* waterbodies are usually privately owned and fished exclusively by their owners. Against this general pattern, 21 of 179 floodplain *kuas* were leased out for some fishing activities, while 2 of 75 river *kuas* were owned by villages instead of individuals.

The 10 perennial *beel* waterbodies were either owned by villages (4 of 10) or reportedly available for free fishing (5 of 10, one unknown).

The 19 perennial river sections had more variable ownership, with 3 waterbodies owned by the Ministry of Land for leasing as *jalkars*, 3 owned by villages, 4 owned by the Water Development Board (sections on either side of sluice gates) and one privately owned section. Eight of the 19 river sections were available for free fishing.

- *Excavation*

All the floodplain, river and household *kua* waterbodies were reportedly created by excavation, to produce fish pits of sufficient depth to attract fish as the dry season approached. River waterbodies were mostly unexcavated, though some waters, especially those close to the sluice gates, were deepened or maintained through excavation. In contrast, none of the *beel* waters were excavated.

- *Use of fish attracting devices (FADs)*

The owners of nearly all the waterbodies used some type of structures as fish attracting devices (FADs, Figure A1.1d). Such structures are placed in the deeper parts of the waterbodies to provide refuges for fish as the dry season approaches, and then removed after being surrounded by seine nets (*katha*), or when the waters become low enough for pump dewatering (*kua*). The larger B, R, RKU and FKU waterbodies generally used tree branches, bamboo or water hyacinth as FADs, while the small household *kuas* were usually only supplied with water hyacinth FADs.

- *Fertilisation*

Before fishing, 12-58% of the owners of B, R, RKU and FKU waterbodies would attract fish into their *katha* brushpile and *kua* pits from the surrounding waters by fertilising with materials such as oil cake, rice, rice bran, wheat bran and cow dung. Such fertilisation was generally not used in the smaller HKU ponds (Figure A1.1c), unless the ponds had been stocked with fish.

- *Fish stocking*

Small amounts of fish were stocked in up to 11% of the waterbodies of each type. Fish species stocked included *Clarias batrachus*, *Catla catla, Cyprinus carpio, Cirrhinus mrigala, Hypophthalmichthys molitrix, Labeo rohita* and *Oreochromis mossambicus.* The dates of stocking of such fish, usually during the high water season between June and October, suggest that they were either stocked into closed fish ponds (which should not have been included in the sample) or released into floodplain waters for the general benefit of the village communities (whose owners may assume that such fish would still be in their waterbodies later in the dry season).

5.3 Dry season fishing activities, gear use and catches

Fishing in dry season waterbodies was done by over ten different gear types (Table A1.3). *Katha* brushpile traps were used in the perennial waterbodies which remain too deep for dewatering. In the smaller *kua* pits, traps, cast nets, gill nets, seine nets and spears were all used as water levels declined, and then finally, the last fish were caught by dewatering the *kuas* with diesel pumps or by hand.

Quite surprisingly, the largest total catches in the dry season were taken from the smallest household *kua* waterbodies (Table A1.4). This reflects their great abundance on these floodplains, with most households having some sort of pond beside their house. The second largest total catches were taken from the floodplain *kuas*, also small but very common on the floodplain. The perennial *beels* and river sections produced the next largest catches and the river *kua* waterbodies gave the least catches (Table A1.4).

Total catches were over four times greater outside the FCDI scheme than inside (Table A1.4), particularly due to the very large catches from outside household *kua* ponds. The productivities of the outside waterbodies, measured as kg/ha (weights in Table A1.4, areas in Table A1.1), were also much higher than inside for four of the five waterbody types. Such productivities were particularly high (176 to 6,790kg/ha!) for the floodplain and household *kua* waterbodies, demonstrating the high concentrations of fish left in such floodplain depressions as water levels decline.

5.4 Seasonality of dry season fish catches

Fish catches were taken from some dry season waterbodies as soon as they became distinguishable, as water levels declined from the floodplain. Total catches were small in the early dry season, in November, rose to a maximum in either December, January or February (Figure A1.2), and then gradually declined until either the waterbodies dried up, or the catch rates became so low as to make further fishing unprofitable. In most waterbodies, fishing continued only up to March or April: only three of the 28 waterbodies were fished right through to the end of the 1996 dry season in May (Table A1.5).

Over and above this general pattern, there was much variability in the catch seasonality of the different waterbodies. Most of the larger river and *beel* waterbodies were fished over most of the dry season months. The other *kua* waterbodies, in contrast, were fished for shorter periods, sometimes only one or two months. This pattern partly reflects the sizes of the different waterbodies, and partly their ownership. The larger waterbodies are usually fished competitively by fishermen from their nearby villages, and hence fishing begins early in the season. The smaller *kua* waterbodies, in contrast, are nearly all privately owned, so that their owners may choose to delay fishing until water levels are low enough to maximise the efficiencies of their gears.

5.5 Escapement from the dry season fishery

- *Absolute escapement*

Fish catch rates from the dry season waterbodies generally declined over the months, as fish stocks became depleted by fishing and natural mortalities (Figures A1.3a,b). In several of the waterbodies, however, catch rates actually rose between the first and second months, presumably because the falling water levels made the fish more easily contained, or the gears more effective, or both. In these cases, any low points early in the series were not included in the Leslie depletion model for the estimation of fish escapement.

In 18 of the 28 monitored waterbodies, the last gear to be used in the dry season was dewatering, either by diesel pump or by hand. For these waterbodies, it was assumed that all the fish were fully caught so that escapement was zero[2]. Six of the 28 waterbodies (R3 and FKU1 inside and B3, R6, FKU4 and FKU5 outside) were estimated to have allowed some escapement of fish (Table A1.5, Figures A1.3a,b). Of the other 4 waterbodies, *beel* B1 was dewatered to provide irrigation water, waterbodies R1 and RKU6 had insufficient data to use the Leslie model, and *beel* B4 produced a population estimate smaller than the actual catch estimate, presumably due to sampling errors.

The escapement estimates in Table A1.5 are likely to be imprecise: three of the six estimates (for FKU3, FKU4 and FKU5) are based on only the last two or three data points, where the earlier points appeared to be below the expected levels for reasons mentioned above. The cast net CPUE data for the inside FKU1 waterbody gave an estimate of 16kg escapement using the last three data points, but only 2kg using the last two points (Figure A1.3a). The seine net data for waterbody FKU4 gave estimates of 31 and 79kg escapement for two and three points respectively up to April, while the last two cast net data points estimated escapement of only 7kg, but up to the following month of May. The latter (lower) estimate was adopted for this waterbody. While such estimates are thus imprecise, selecting only the final two or three data points does reduce the estimate in each of these cases so that the escapement predictions are likely to be cautious rather than optimistic.

Based on the six Leslie model results, total escapement was then estimated by raising the escapement within the 28 waterbodies to the total numbers of waterbodies in the inside and outside study regions:

Waterbody Type	Estimated Escapement Inside FCDI scheme	Estimated Escapement Outside FCDI scheme
Beel	0 kg	807 kg
Rivers	360 kg	292 kg
Floodplain *kuas*	227-1818 kg	1807 kg
River *kuas*	0 kg	0 kg
Household *kuas*	0 kg	0 kg
Total	587-2178 kg	2906 kg

These very approximate escapement estimates suggest that less fish survive over the dry season inside the FCDI scheme than outside. All of the surviving fish were contained in the perennial *beel* and river waterbodies, and the abundant floodplain *kuas*. No fish were estimated to have survived over the whole dry season in the small household *kuas* or the river *kuas*.

- *Proportional escapement*

---

[2] Some fish such as snakeheads may survive even in dewatered waterbodies by burrowing into the mud to avoid capture.

Proportional escapement, or survival rates over the dry season period were simply calculated as the escapement divided by the estimated initial populations. With such figures based on weights rather than numbers, the estimates assume zero growth during the dry season, and also assume zero natural mortality in the days after the end of the fishing activities. For 18 of the waterbodies, of course, no fish survived due to the use of dewatering or the natural drying of the ponds. For the six waterbodies in which some fish did escape the fishery, dry season survival rates varied between 1.6 and 21% (median 4%), equivalent to instantaneous total mortality coefficients of Z = 4.11 to 1.55 (median 3.14).

Overall proportional escapement was also calculated from the total escapements (text table above) and the total catches (Table A1.4), as 0.54-1.9% inside the FCDI scheme and 0.6% outside (Z=5.2 to 4.0). These figures take account of those waterbodies with zero escapement, and provide a better indication of the overall dynamics of Bangladeshi floodplain fish stocks.

5.6 Species composition of dry season fish catches

- *Numbers of fish species*

The numbers of fish species in the catches from dry season waterbodies invariably declined as the season progressed, presumably as the least common species became fished out, or as the non air-breathing species died in the deoxygenated conditions (Table A1.6).

In five of the six combinations of waterbody type and season in which data were available, fish communities were richer outside the FCDI scheme than inside (Table A1.6). Only the *beel* fish communities comprised more species inside the scheme, reflecting the large *beel* habitats available in the inside region (Table A1.1).

Fish communities were also richer in the larger, perennial *beel* and river waterbody types than in the *kua* waterbodies. The smallest household *kuas* were the least species rich of all the waterbodies (Table A1.6).

- *Species compositions*

Fish species compositions were noticeably different inside and outside the FCDI scheme. Smaller species such as *Anabas testudineus, Channa punctatus* and *Puntius sophore* were generally more common inside than outside (Figure A1.4a). The large catfish *Wallago attu* was especially common outside the FCDI in all waterbodies.

As implied by the preceding section, several species present in the early dry season were not present in the late dry season. Following this pattern, the large carps *Catla catla*, *Cirrhinus reba* and especially *Labeo rohita* were caught in both the inside and outside waterbodies, particularly in the perennial *beels* and rivers in the early dry season (Figure A1.4a): such species were then noticeably less common in the late dry season, though some *L. rohita* and *C. reba* were still caught (Figure A1.4b). Late dry season catches were dominated by the two predators *Channa marulius* inside the FCDI scheme, and by *W. attu* outside. The latter species did not survive well inside the FCDI scheme, even though high catches were sustained for the full dry season outside. More surprisingly, the air breathing *A. testudineus* and *C. punctatus*, both dominant in the early dry season inside *kua* catches, were both quite rare in all waterbodies in the late dry season.

In general, the perennial *beel* and river waterbodies contained more of the large high value species such as *C. marulius* and *L. rohita* (Figure A1.4a). The smaller *kua* waterbodies contained mostly smaller species such as *A. testudineus, C. punctatus* and *P. sophore*.

5.7 Age composition of dry season fish catches

Growth rates of fish were estimated from the two-year time series of length-frequencies taken under the routine sampling programme (see Section 5.7, main report). By examining the length frequencies from dry season waterbodies in comparison with the overall time series discussed in Section 5.7, it was evident that nearly all the fish living in dry season waterbodies were only up to one year old (Figures A1.5a-f). Of the 10,687 fish measured for length in this sub-project, only three *Anabas testudineus*, one *Glossogobius giurus*, three *Puntius sophore* and perhaps 6-10 *Wallago attu* were found significantly larger than the main '0+' cohort, and considered likely to have been one to two year old fish. All of these larger fish were caught in the perennial *beel* and river waterbodies[3], except for two of the three *P. sophore*, taken from *kuas*. The few larger fish were present both inside and outside the FCDI scheme.

The sampled fish generally grew only small amounts over the monitored dry season period from January to May, supporting the conclusions from the growth studies (Section 5.7, main report) that most of the growth takes place over the high water season. Though these fish lengths were not analysed statistically, five of the key species showed no obvious consistent differences between the sizes of fish residing inside and outside of the FCDI scheme. One species *Wallago attu* appeared consistently larger inside the FCDI scheme than outside (Figure A1.5f), as found in the main growth studies.

6. Discussion

This sub-project has shown that the largest areas of water available to fish in the dry season are in the perennial *beels*, rivers and household *kuas*. The largest total catches, predictably, are taken from these waterbodies, in addition to the medium-sized floodplain *kuas*, in which fish become highly concentrated. Outside the FCDI scheme, an estimated 75% of the total dry season catch (not including that from the main river) was taken from the small household *kuas*. This suggests that these waterbodies are far more important than previously supposed - they were not even included as a habitat type in the FAP17 assessments of floodplain fish production (FAP 17, 1994)!

Of the fish caught in the dry season waterbodies, more than 99% were identified as the less than 1-year old recruits spawned at the beginning of the preceding flood. The enormously high mortality rates among Bangladeshi fish mean that each new year's recruitment is produced almost entirely from the few fish left over at the end of the dry season. Key management issues are then where do these fish survive?, and could fish catches be increased by increasing the dry season escapement? This sub-project has gone part of the way to answering these questions; some of the other uncertainties are being investigated elsewhere in the project.

About survival locations, it is clear that small but significant quantities of fish survive in dry season waterbodies, particularly in the larger, perennial *beels* and rivers. The abundant household *kuas* rarely support fish over the dry season simply because they usually dry out. Inside the FCDI scheme, the dry season survivors represent only about 0.09 to 0.34% of the 636t total catches taken during the 1995/96 flood year. The 2.91t of fish estimated to have survived outside the FCDI scheme, similarly represent only 0.32% of the fish caught in that region.

The least known factor about fish survival locations is the relative amount of fish which survive over the dry season in the main rivers not studied during this sub-project. Compared to the floodplain waterbodies, the Padma and Jamuna main rivers are veritable inland seas, which

[3] The lack of old fish in *kua* waterbodies may also reflect the very small length frequency sample sizes taken from these waterbodies.

could never be ‘fished out’ to the extext that occurs on the floodplain. The production of fish on the outside floodplains is probably supplemented significantly by recruitment arising from the main river fish. The inside floodplains of the study region, however, could only be recruited from this source by fish passing in to the FCDI scheme through the sluice gates. In sub-project 3, it was estimated that 0.89-4.0t of fish did enter the FCDI scheme early in the flood season, followed by a possible 0.28-2.57t of mostly larger fish, including major carps, in the early ebb season.

The above figures suggest that a similar order of magnitude of fish migrates into FCDI scheme through the sluice gates, as survives over the dry season inside it, with both sources being extremely small compared to the eventual production. This impression needs some clarification, however. Due to the delayed 1996 flood, the sluice gate immigrants were mostly newly spawned recruits, not mature adults preparing to spawn. The 0.59-2.18t of adult fish surviving inside the FCDI scheme up to the end of the flood season in May could therefore have produced many more recruits than the 1.17-6.57t of fry estimated to have passed through the sluice gates between July and September. Furthermore, due to the water flow patterns, many of the immigrant fish would have been rapidly caught by the abundant lift nets just inside the sluice gates, further reducing the real contribution of the outside recruitment to the inside productivity. In comparison, the ‘inside survivors’ would be able to disperse from the ponds on to the floodplain with the rising floodwaters largely without obstruction.

Floodplain fish stocks are clearly adapted to survive in very difficult conditions, and to rebuild stocks rapidly from very low numbers. It seems incredible that fish production inside the FCDI scheme could be derived from such minimal sources of recruitment. Other species with annual life cycles include the majority of squid stocks: these are generally managed for a target proportional escapement of 40% to ensure good recruitment for future years (Beddington *et al*, 1990), compared to the less than 1% seen here for floodplain fish. It is possible, then (as indeed found in Sub-Project 2) that more fish do actually survive in dry season waterbodies than detected by depletion fishing, due to their variable skills at avoiding capture. Fishermen in dry season waterbodies were also reported by field staff to be less careful in their fishing towards the end of the dry season as they perceived that most of the fish had already been caught: this would again lead to underestimation of the escapement rates. It is also possible that more fish may survive in the larger Gandahasti Beel, just outside the study site. Finally, it is possible that some fish do enter the PIRDP through the sluice gates as eggs and very small fry, before the floodplains are inundated.

In the absence of reliable information on alternative possible sources of recruitment, it is concluded that dry season waterbodies inside the FCDI scheme are responsible for the majority of new recruits giving the next year’s fish production. Since the fish communities in dry season waterbodies were observed to become less species rich as the dry season progressed, the long-term species diversity inside the FCDI scheme is clearly also maintained by fish migrating in through the sluice gates. Both sources of recruitment are therefore vital to the health and abundance of the fishery.

From a management perspective, the perennial *beels* and rivers and the larger floodplain *kuas* inside the FCDI scheme may be viewed as community resources, mainly responsible for maintaining the inside fishery. Protecting fish in these waterbodies should be seen as a key management objective. To maintain productivity for the future, fishing communities should be encouraged to resist the temptation to fish out such waterbodies, even when hydrological conditions permit. This could be achieved by the use of a number of reserve waterbodies, or simply by the application of restraint towards the end of the dry season, by which time fish catches are already small. Local communities should be responsible for choosing such reserve or restraint waterbodies, which should clearly be of the deeper perennial type.

It is also possible that fish production could be enhanced by increasing the numbers of fish allowed to survive in the dry season waterbodies. The potential of such an approach depends on the density dependence of mortality, recruitment and growth during both the dry season and the following flood. It is for instance possible that if more fish were left in the drying waterbodies, then more of them would simply die by natural causes, either in the deoxygenated waters, or by losses to the abundant predators. It is also possible that if recruitment was say doubled, there would be inadequate floodplain resources during the flood season to support the extra fish. Such factors are being studied by sub-projects 2 and 4 of this investigation. If fish production *is* limited by recruitment (as seems likely!), a sacrifice of perhaps around 2% of the 108t inside dry season catch, which would double the recruitment from inside waterbodies (assuming a linear stock/recruit relationship at these low stock levels), could then also double the next year's catch from the current 636t to perhaps over 1,000t. From a community perspective, such a potentially enormous tradeoff would surely be worth investigating.

Though dry season waterbodies are clearly vital for the inside fisheries, it is also clear that they are not the sole source of recruitment. Since fish communities are less species rich in the dry season (56 species recorded inside the FCDI scheme, Table A1.6) than for the year as a whole (64 species, Section 5.4.2, main report), and become even more depleted by the end of the dry season (43 species), then these missing fish species must be maintained by recruitment from outside the FCDI scheme, and probably from the main river. Since the main river could never be fished out as completely as the floodplain waterbodies, these fish stocks may have their own inherent protection by virtue of their lifestyle. Their access to inside floodplains could however be maintained by simple management of the sluice gates to permit immigration whenever possible given the hydrological conditions. Restraints could also be placed on lift net fishermen to restrict their fishing at channel positions inbetween the sluice gates and the floodplains beyond.

7. Summary

- This sub-project investigated the types of habitats used by fish to survive over the dry season period, and the weights of fish surviving, in the presence of normal fishing activites. The work was done to determine the relative importance of dry-season survivors to the breeding stocks responsible for the recruitment at the start of each new flood year.

- The field work was undertaken over the 1995/96 dry season, from the start of the *kua* and *katha* fishing season in November 1995, until the end of the dry season in May 1996. The field research involved two main stages: firstly, the numbers and areas of perennial *beels* and river sections and three types of *kua* pits were quantified by household and village interviews inside and outside the FCDI scheme; detailed catch information was then monitored on a randomly selected sub-sample of 2-3 waterbodies of each type in each region. Species composition and length frequency data were also recorded to identify which types of fish survived in dry season waterbodies.

- The escapement of fish (the weight of fish *not caught* over the dry season) was estimated using a depletion model on those waterbodies which did not dry out naturally, and were not fished out by dewatering at the end of the dry season.

- The perennial *beel*s and rivers were largest in size but fewest in number. Floodplain *kua* waterbodies were medium sized but common, while the household *kua* or *mathel* ponds were very small but extremely common. Reflecting their sizes and numbers, the total dry season areas of waterbodies were highest for rivers, followed by household *kuas* and then *beels*.

- Water retention was reported to depend mainly on the sizes of the waterbodies, with the *beels* and river sections usually keeping some water throughout the dry season at average minimum depths of 0.5-2.4m. In contrast, only up to 50% of floodplain and river *kuas* and 13-15% of household *kuas* did not dry out. Most of the latter waterbodies dried out as early as January.

- The small *kua* waterbodies and household ponds were usually privately excavated, owned and fished. The perennial *beel* and river waterbodies in contrast were naturally created, and either owned by villages, leased out as *jalkars* or available for free fishing.

- Fish attracting devices, such as tree branches, were used in nearly all dry season waterbodies to maximise fish catches. Fertilisation was also used in 12-58% of the larger waterbodies, while small amounts of fish were stocked in up to 11% of the waterbodies.

- On an individual basis, the largest fish catches were taken from the largest and deepest *beel* and river waterbodies, particularly in *katha* brushpile traps. Overall, however, the largest total fish catches were taken from the small household *kua* ponds, followed by the floodplain *kuas*, particularly by dewatering and seining gears. Total fish catches in dry season waterbodies were over four times greater outside the FCDI scheme than inside, mainly due to the productive and abundant household *kua* ponds.

- The main dry season fish catches were taken in the middle of the season, in December, January or February. In most of the monitored waterbodies, fishing continued only up to March or April: only three of the 28 waterbodies were fished right through to the end of the 1996 dry season in May. The perennial *beel* and river waters generally had longer fishing seasons, reflecting their open accessibility, while the *kuas* were usually fished for fewer months by their owners, to maximise efficiency.

- Eighteen of the 28 monitored waterbodies were dewatered as the final fishing activity, and were presumed to have allowed zero escapement of fish. Six of the other ten waterbodies (two inside the FCDI scheme, and four outside) did not dry out, and were estimated to have retained some fish over the full dry season. All the surviving fish were in the perennial *beel* and river waterbodies, and the abundant floodplain *kuas*, with none in the small household *kuas* or the river *kuas*. Raising to the full numbers of waterbodies, a total of up to 0.6-2.2 tonnes of fish were estimated to have survived over the dry season inside the FCDI scheme, and 2.9t outside. These very small escapements represent only 0.54-1.9% and 0.6% of the estimated fish populations at the start of the dry season.

- The numbers of fish species in the catches from dry season waterbodies were invariably lower at the end of the season than at the beginning; the major carps were among those species less common at the end of the season, when catches were dominated by predatory catfish and snakeheads. In five of the six available combinations of waterbody type and season, fish communities were richer outside the FCDI scheme than inside. Fish communities were also richer, and included more of the larger, valuable species in the perennial *beel* and river waterbody types than in the *kua* waterbodies, with the small household *kuas* being the least species rich.

- Over 99% of the fish caught in the dry season waterbodies were only up to one year old, having been spawned at the start of that flood season.

- The relative importance of fish recruitment arising from the dry season survivors and from those fish migrating in through the sluice gates was discussed. It was tentatively concluded that the inside survivors produce most of the recruitment, while the immigrant fish are responsible for maintaining species diversity. Both sources of recruitment are therefore important for the health and productivity of the fisheries inside FCDI schemes.

- From a management perspective, it was recommended that the perennial *beels*, river sections and *kuas* should be viewed as community resources vital to the sustainability of fisheries production inside FCDI schemes. Local communities should be encouraged to restrain their exploitation rates in perennial waterbodies towards the end of the dry seasons, both to conserve fish stocks and for the enormous potential gains in productivity in the following flood.

- Due to the low species diversity in dry season waterbodies, with the major carps among those species becoming rare or absent by the end of the dry season, restraints on dry season fishing would still not protect all the species available in this area. To maintain the maximum catch diversity inside the FCDI scheme, sluice gates should also be operated to allow fish immigration whenever possible.

8. Acknowledgements

This research was funded under Project R5953, 'Fisheries Dynamics of Modified Floodplains in Southern Asia' of the ODA Fisheries Management Science Programme. The authors particularly wish to thank the owners and fishermen of the 28 surveyed waterbodies at the Pabna study site for their generous help and cooperation during the seven month study.

9. References

Beddington, J.R., A.A. Rosenberg, J.A. Crombie & G.P. Kirkwood, 1990. Stock assessment and management advice for the short fin squid fishery in Falkland Island waters. Fisheries Research, 8: 351-365.

FAP 17, 1994. Fisheries Studies and Pilot Project, Final Report (Draft), June 1994.

Table A1.1 Numbers and dimensions of dry season waterbodies inside and outside the Pabna FCDI scheme study site.

Waterbody Types	Inside FCDI scheme	Outside FCDI scheme
Beel		
Number of waterbodies	4	6
Size (ha, mean and range)	52.5ha, 5-100	14.6ha, 3-30
Total area (ha)	210	88
River		
Number of waterbodies	12 sections (widths<100m)	7 sections (widths<100m)
Size (ha, mean and range)	2.93ha, 0.5-6	11.29ha, 2-30
Total area (ha)	352	790
Floodplain Kuas		
Number of waterbodies	343	417
Size (m^2, mean and range)	1033 m^2, 60-7200	190 m^2, 48-1500
Total area (ha)	35	10
River Kuas		
Number of waterbodies	49	26
Size (m^2, mean and range)	391 m^2, 25-2400	279 m^2, 25-1500
Total area (ha)	19	7
Household Kuas		
Number of waterbodies	2684	4868
Size (m^2, mean and range)	97 m^2, 6-500	84 m^2, 15-400
Total area (ha)	263	411

Table A1.2 Dry season water retention in waterbodies inside and outside the Pabna FCDI scheme study site.

Waterbody Types	Inside	Outside
Beel		
% of waterbodies retaining water	50% (2 of 4)	100% (6 of 6)
Min. dry season depth (m, mean & range)	0.5, -	1.6, 0.5-3.0
Average date of dessication (mean & range)	15/3, -	-
River		
% of waterbodies retaining water	100% (12 of 12)	100% (7 of 7)
Min. dry season depth (m, mean & range)	1.3, 0.8-3.0	2.4, 0.3-5.0
Average date of dessication (mean & range)	-	-
Floodplain Kuas		
% of waterbodies retaining water	50% (39 of 78)	15% (15 of 102)
Min. dry season depth (m, mean & range)	0.7, 0.3-1.5	0.7, 0.3-2.0
Average date of dessication (mean & range)	30/3, 1/2-1/6	11/3, 15/10-1/6
River Kuas		
% of waterbodies retaining water	29% (14 of 49)	4% (1 of 26)
Min. dry season depth (m, mean & range)	1.0, 0.3-2.5	1.0, -
Average date of dessication (mean & range)	28/3, 1/2-15/6	11/5, 1/1-1/6
Household Kuas		
% of waterbodies retaining water	15% (9 of 61)	13% (15 of 119)
Min. dry season depth (m, mean & range)	0.4, 0.3-0.5	0.6, 0.3-1.0
Average date of dessication (mean & range)	29/1, 1/11-15/4	10/1, 15/10-15/4

Notes: Minimum depths calculated on only those waterbodies retaining some water
Average dessication dates calculated on only those waterbodies which dry out

Table A1.3 Total catches (kg, upper block) and fishing efforts (lower block) taken in the 28 monitored dry season waterbodies, by geartype and month (small gears not sampled for *beel* and river waterbodies).

(Table unavailable)

Table A1.4 Estimated total catches (kg) by gear type (not including 'small' gears in *beels* and rivers) from dry season waterbodies from November 1995 to May 1996, inside and outside the PIRDP FCDI scheme.

Waterbody Type:	*Beel*	River Section	Flood-plain *Kua*	River *Kua*	House-hold *Kua*	Total
Inside FCDI Scheme						
Active Trap			194		4026	4220
Cast Net			8781		4294	13075
Drag Net			1715			1715
Dewatering (Hand)		1360	9776	4328	16775	32239
Fixed Gill Net			1372		2192	3564
Hand Fishing			892		1253	2144
Katha	12748	19000				31748
Kua	90		800			890
Others			143		895	1038
Seine Net			515		16909	17424
Spears			172			172
Total	12838	20360	24359	4328	16344	108229
Outside FCDI Scheme						
Active Trap					4057	4057
Cast Net			3753	2	99794	103549
Drag Net						
Dewatering (Hand)		70	2502	2253	21095	25920
Fixed Gill Net			5838			5838
Hand Fishing				17	811	829
Katha	23304	7786				31090
Kua	120	1393			24340	25853
Others				52	62067	62119
Seine Net			55670	22	156587	212279
Spears			139		6491	6630
Total	23424	9249	67902	2346	357242	478163

Table A1.5 Monthly total catches (kg) taken in the 28 monitored dry season waterbodies (not including small gear catches for *beel* and river waterbodies), and waterbody areas and estimated escapement.

Waterbody position and type	Waterbody area (m^2)	Monthly catches (kg)							Total Catch (kg)	Escap-ement (kg)
		Nov. 95	Dec. 95	Jan. 96	Feb. 96	Mar. 96	April 96	May 96		
INSIDE										
Beels										
B1	130,000		160	880	992	20			2,052	0
B2	50,000		1,960	800	800	560	247		4,367	0
Rivers										
R1	15,000		10		18				28	0
R2	40,000		1,030	450	335	173	361		2,349	0
R3	50,000	335	1,225	648	121	267	117		2,713	90
FP. *Kuas*										
FKU1	750		20	8	13	12	5	1	59	2-16
FKU2	300				70		7		77	0
FKU3	600			1	48	13	16	0	77	0
River *Kuas*										
RKU1	300			80	10	10			100	0
RKU2	300				5	30			35	0
RKU3	750				30	100			130	0
HH. *Kuas*										
HKU1	120	1		2	19	9			30	0
HKU2	32	0	1	0	2				4	0
HKU3	40		2	2	15				18	0
OUTSIDE										
Beels										
B3	150,000		185			1,185	4,675	138	6,138	269
B4	15,000	785		320	160	185	175		1,625	0
Rivers										
R4	60,000		190	840	122	100	120		1,372	0
R5	300,000	87	280	252	27	462	169		1,277	0
R6	70,000	205	444	279	214	82	92		1,316	125
FP. *Kuas*										
FKU4	1500		3	251	115	41	10		420	7
FKU5	375			30	10	0	0		41	6
FKU6	300				28				28	0
River *Kuas*										
RKU4	225					20			20	0
RKU5	1500					220	20		240	0
RKU6	450		6		2		3		11	0
HH. *Kuas*										
HKU4	225		23	1	14	34	41		113	0
HKU5	105	4	6	19	6	5	3		42	0
HKU6	100		2	49	17	8			76	0

Table A1.6 Total numbers of species recorded in catches from dry season waterbodies in the early (November to March) and late (April and May) dry season, inside and outside the PIRDP FCDI scheme, by waterbody type ('-' indicates zero catches or missing species composition data).

Waterbody types:	*Beel*	River Sections	Flood-plain *Kua*	River *Kua*	House-hold *Kua*	Total
Inside FCDI Scheme						
Early dry season	48	52	37	30	27	56
Late dry season	34	32	18	-	-	43
Outside FCDI Scheme						
Early dry season	43	59	41	-	36	63
Late dry season	36	35	-	-	21	48

Figure A1.1 Dry season fish catches, as reported by census interviewees, plotted against waterbody areas for each waterbody type (A) and position relative to the FCDI scheme (B), and in the presence and absence of fertilisation (C) and fish attracting devices (FADS, D), and plotted against minimum dry season water depths (E).

Figure A1.2 Estimated total fish catches in dry season waterbodies, by waterbody type and month, inside and outside the FCDI scheme (upper and lower series respectively).

Figure A1.3a 'Leslie' depletion plots of CPUE abundance indices for cast net (CN), seine net (SN) and *katha* (KT) gear types against cumulative catches, for floodplain *kua* (FKU) and *beel* (B) waterbodies inside (In) and outside (Out) of the FCDI scheme. Data from Table A1.3, summarised within monthly time periods.

Figure A1.3b 'Leslie' depletion plots of CPUE abundance indices for *katha* gears against cumulative catches, for riverine waterbodies inside (In) and outside (Out) of the FCDI scheme. Data from Table A1.3, summarised within monthly time periods.

Figure A1.4a Estimated total catches by waterbody type and fish species in the early dry season (November to March), inside and outside of the FCDI scheme (upper and lower series respectively), for those species comprising at least 0.5% of the total inside or outside catches (species codes given in Table 5.1, main report).

Figure A1.4b Estimated total catches by waterbody type and fish species in the late dry season (April and May), inside and outside of the FCDI scheme (upper and lower series respectively), for those species comprising at least 0.5% of the total inside or outside catches (species codes given in Table 5.1, main report).

Figure A1.5a Length frequencies of *Anabas testudineus* inside (upper series) and outside (lower series) the Pabna FCDI scheme, from 'non-selective' gear types (excluding fixed gill nets), from each waterbody type, in January, March and May 1996. X-scale = 0-21cm fork lengths in half cm classes.

Figure A1.5b Length frequencies of *Catla catla* inside (upper series) and outside (lower series) the Pabna FCDI scheme, from 'non-selective' gear types, from each waterbody type, in January, March and May 1996. X-scale = 0-48cm fork lengths in 1cm classes.

Figure A1.5c Length frequencies of *Channa striatus* inside (upper series) and outside (lower series) the Pabna FCDI scheme, from 'non-selective' gear types, from each waterbody type, in January, March and May 1996. X-scale = 0-51cm fork lengths in 1cm classes.

Figure A1.5d Length frequencies of *Glossogobius giurus* inside (upper series) and outside (lower series) the Pabna FCDI scheme, from 'non-selective' gear types, from each waterbody type, in January, March and May 1996. X-scale = 0-26cm fork lengths in 1cm classes.

Figure A1.5e Length frequencies of *Puntius sophore* inside (upper series) and outside (lower series) the Pabna FCDI scheme, from 'non-selective' gear types, from each waterbody type, in January, March and May 1996. X-scale = 0-11cm fork lengths in half cm classes.

Figure A1.5f Length frequencies of *Wallago attu* inside (upper series) and outside (lower series) the Pabna FCDI scheme, from 'non-selective' gear types, from each waterbody type, in January, March and May 1996. X-scale = 0-82cm fork lengths in 1cm classes.