Government of the Peoples Republic of Bangladesh
Flood Action Plan

FAP 17

Fisheries Studies and Pilot Project

FINAL REPORT

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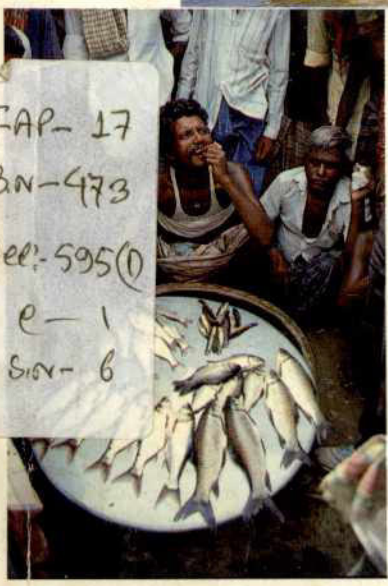
Appendix 3



FISHERIES AND SOCIOECONOMIC METHODS

ODA
Overseas Development Administration, U.K.

FAP 17

FINAL REPORT

APPENDIX 3

**** Draft ****

Fisheries and Socioeconomic Methods

FAP 17
FISHERIES STUDIES
AND PILOT PROJECT

June, 1994

Funded by ODA in conjunction with the Government of Bangladesh

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ABBREVIATIONS AND ACRONYMS

ADAB	Association of Development Agencies of Bangladesh
AEU	Agro-Ecological Unit
ANOVA	Analysis of Variance
BBS	Bangladesh Bureau of Statistics
BFRSS	Bangladesh Fisheries Resource Survey System
CAS	Catch Assessment Survey
CPP	Compartmentalization Pilot Project
CPUA	Catch Per Unit Area
CPUE	Catch Per Unit Effort
DAM	Directorate of Agricultural Marketing
DoF	Department of Fisheries
EUS	Epizootic Ulcerative Syndrome
FAD	Fish Attraction Device
FAO	Food and Agriculture Organization
FAP	Flood Action Plan
FAP 3	Flood Action Plan Study No. 3 (North Central Regional Study)
FAP 16	Flood Action Plan Study No. 16 (Environmental Study)
FAP 17	Flood Action Plan Study No. 17 (Fisheries Studies and Pilot Project)
FAP 20	Flood Action Plan Study No. 20 (Compartmentalization Pilot Project)
FCA	Fish Catch Assessment
FCD/I	Flood Control and Drainage with or without Irrigation
FES	Fishing Effort Survey
GLIM	Software for Statistical Analysis
ha	hectare(s)
ICLARM	International Centre for Living Research Management
IVS	International Volunteer Services
kg	kilogram(s)
km	kilometre(s)
LRA	Land Resource Appraisal
mg/l	milligram per litre
MIKE11	A microcomputer based modelling system for rivers and channels
MSE	Mean of Squares due to error
NGO	Non Government Organization
NMM	Net Marketing Margin
ODA	Overseas Development Administration
pH	Measure of acidity and alkalinity of water (log of hydrogen ion concentration)
RRA	Rapid Rural Appraisal
RSSR	Reconnaissance Soil Survey Reports
SSE	Sum of squares due to error
STD	Standard deviation
TGA	Target Group Approaches
UNDP	United Nations Development Project
WB	World Bank

GLOSSARY

The following is a glossary of Bangla terms encountered during the course of FAP 17 research. It is not a definitive taxonomy of Bangla terms concerned with fisheries and aquatic resources. Such an undertaking would require taking into account the fact that terminologies and usages change radically from region to region and even from village to village. The aim, rather, is to highlight the different meanings some of these words and terminologies may have in different parts of the country. The region(s) where the term occurs is (are) indicated. Cross references to other entries in the glossary are indicated in small capital letters.

The Roman alphabet is rather poor as a vehicle for communicating Bangla terms, and the versions given here make no pretence at being definitive. There is no standard procedure for transliterating Bangla, and marked differences in the regional pronunciation of words mean that different spellings of the same word may be equally "correct" in terms of the sound of the word.

Terms used to describe actors in fish trading system

aratdar	NC/NW/ NE/SW	Fish wholesaler. A key figure in the marketing chain. Generally the source of credit inputs into the marketing system, advancing money to other actors in the system to ensure fish supply. Usually based in district wholesale markets.
bepari		*Bepari* is a professional fish trader. He purchases fish from *FARIA* or fishermen and sells high fish to retailers or other distributors.
chalani	NC/NW/ NE/SW	People who transport fish from district wholesale markets to higher-level markets. Limited to the carriers.
faria		Small traders who purchase fish directly from fishermen and sell to *BEPARI*.
nikari	NC/NW/ NE/SW	A generic term for fish traders. Occasionally used for Muslims involved in fisheries activities of any kind.
paikar	NC/NW/	Fish trader.

Terms used to describe water bodies

beel	NC/NW/ NE/SW	Officially, a "back swamp" or depression. Can be either perennial or seasonal. In reality it used for a wide variety of freshwater bodies (oxbow lakes, old river beds, *KHAL*, even artificial channels). Often refers to flooded areas with no obvious deeper section or depression that used to have perennial areas of water.
haor	NC/NW/ NE/SW	Depression on the floodplain located between two or more rivers, which functions as a small internal drainage basin.

jalmahal	NC/NW/ NE/SW	A "water estate", now referring to any area of *KHAS* water body controlled by the government and normally leased out for fisheries.
katha	NC/NW/ NE/SW	Cut branches of trees submerged in *BEEL* to attract fish.
khal	NC/NW/ NE/SW	Artificial or natural channel, small river or canal.
kua	NC/NW/SW	Artificial fish pit excavated in the floodplain or *BEEL*. Deeper than a *DANGA*. In the South West Region, sometimes used for borrow pits near homesteads or roads.

Terms used to describe administrative divisions and human settlements

mauza	NC/NW/ NE/SW	The smallest recognised administrative unit. It not the same as a village. Some *mauza* in the *HAOR* area have no villages in them at all although a *mauza* can cover anything from a single village or hamlet to 12 or more villages.

1 OBJECTIVE

FAP 17: Fisheries Studies and Pilot Project, was one of the supporting studies of the Flood Action Plan. It was the only FAP project entirely devoted to inland fisheries issues. FAP 17 was designed as a two-phase project. Phase I, the Fisheries Studies, was a biological and socioeconomic research project which aimed to provide baseline data on capture fisheries and to provide impact assessments of a range of different types of FCD/I projects on fish resources and on the fishing communities dependent to varying degrees on these resources.

FAP 17 Phase 1 has seven immediate objectives:

1. Development of guidelines for the assessment of impacts of future flood control measures on communities and the fisheries resources they use.

2. Assessment of those changes in the economic and nutritional status of different groups which result from the impact of flood control on fish production.

3. Assessment of the factors affecting the flow and distribution of benefits from fisheries production.

4. Evaluation of the effects of different flood control measures on the production of fish.

5. Evaluation of the effects of different flood control measures on the movement and population of fishes.

6. Assessment of the feasibility of technical and developmental measures to compensate for or reduce potential losses to fisheries due to flood control.

7. To increase local expertise in the assessment of fisheries.

Of the seven immediate objectives, five directly concern the fisheries studies (Nos. 1, 4, 5, 6 and 7). The training element of the study (objective No.7) was addressed by on-the-job training of approximately 100 fisheries biologists during the course of the field programme. Training was also given to senior supervisory personnel who were responsible for the management and implementation of fisheries monitoring programmes. These members of management and implementation of fisheries monitoring programmes. These members of staff were professors seconded from different universities in Bangladesh. The remaining objectives were addressed through computerised analyses of the enormous volume of fisheries data accumulated by the study to provide information upon which to base impact assessments (objectives 4 and 5) and recommendations relevant to possible future flood control developments (objectives 1 and 6).

The other two objectives (Nos. 2 and 3) were addressed by the socioeconomic component of the Project. The study set out to analyse the role of fisheries in the livelihood strategies of different social and occupational groups in floodplain communities. These two objectives were achieved by surveying existing consumption patterns, fish supplies, informal and formal marketing and institutional structures that influence fish supplies, gear use and fishing activity through household and community studies.

2 APPROACH

In order to obtain quantitative assessments of the impacts of flood control on fisheries it was necessary to provide accurate detailed estimates of fish production (catch), densities, diversities and movements inside and outside various flood control projects which could then be used in a series of paired comparisons between similar habitat types. For such detailed quantification of multi-gear, multi-species fisheries it was considered essential to use direct enumeration methods. This approach involved the collection of fisheries catch information in defined and measured areas during the actual operation of different gear types ranging from the smallest gears such as *sip*, used by children, to the large-scale gears such as *ber jal*, used by teams of professional fishermen. To do this, enumerators had to interview fishermen and measure catches on the water, whether on shallow floodplains or on very large rivers such as the Jamuna. This approach was highly labour intensive and required rigorous on-site supervision, but was the only method which could provide the level of quantitative and qualitative detail required to fulfil the specific objectives of the fisheries studies.

Initially, alternative approaches to fisheries assessment were considered. These included the use of the existing method of collecting fisheries statistics i.e. the Bangladesh Fisheries Resource Survey System (BFRSS) developed by the Department of Fisheries with assistance from FAO. Another possibility was demographic household and market surveys which have been used in other fisheries studies in Bangladesh, e.g. the Third Fisheries Project. These approaches, however, could not provide the level of quantitative detail of each gear type and fish species which were required to produce a comprehensive set of baseline data.

The value of simple environmental indicators of fish production e.g. the morphoedaphic index* was also explored but found to be of little predictive value in describing floodplain fisheries in Bangladesh.

On the other hand, the FAP 17 socioeconomic research programme has attempted to analyse the relative importance of fisheries in the livelihoods of rural households in a random selection of floodplain communities. The fisheries issue in flood control is usually seen in terms of trade-offs; will overall benefits to agriculture and other sectors exceed the disbenefits suffered by fisheries and those dependent on them? This approach ignores many

* MEI = Total dissolved solid concentration (mg/l) divided by mean water depth (metres).

serious issues regarding distribution and what constitutes a benefit for different groups within the population. However, it offers a starting point for making sense of the complexities of rural livelihoods. Benefits from fisheries, whether in the form of income earned or food obtained, have to be seen in the context of the alternatives open to the household and way in which one source of livelihood is balanced with another through the year.

Originally, the FAP 17 study intended to isolate flood control impacts by looking at communities inside and outside flood control projects. However, the difficulties encountered in identifying, on the one hand, fully functioning flood control projects and, on the other, control areas which have not been impacted by some kind of intervention which mimics flood control (roads, paths, homesteads) limit the usefulness of these direct comparisons taken in isolation. The levels of variability between communities with apparently similar resource bases further complicates the question.

As a result, an understanding of the historical dimension of the community - the changes which have taken place in the surrounding environment; the shifts in patterns of agriculture; employment; settlement and community structure, and the development of new arrangements for control of access to resources, including fisheries - all these processes need to be accurately understood in order to determine whether the current levels of dependence on fisheries result from flood control or other changes taking place irrespective of embankments or water regulation.

In most of the cases studied, flood control is only one of a complex series of changes which are impacting on the fisheries resource and on the way in which that resource is exploited and it has not proved possible to identify, quantitatively, the impacts of flood control *per se* on communities dependent on fisheries. However, the FAP 17 social and economic studies do provide qualified descriptions of these communities and the levels of their dependence on the fisheries resource which can be used as a baseline for monitoring future flood control interventions.

3 SELECTION OF PROJECT STUDY AREAS

3.1 Background

The methods and criteria for the selection of study areas were fully documented previously in the FAP 17 Inception and Interim Reports. In addition, a brief outline was presented in the Main Volume of the Final Report.

The design of the overall sampling programme and identification of project areas and field sites took into account the following factors:

- The necessity to select sampling stations inside and outside existing Flood Control Drainage and Irrigation (FCD/I) projects, to evaluate the impact of a variety of FCD/I projects on fishery production.

- The necessity to sample the fisheries in a broad range of aquatic habitats, extending from main rivers and secondary rivers to floodplain areas and *beel* of varying water depths including both seasonal and perennial water bodies.

- The distribution, diversity, abundance and status of the main fisheries supported by these waters.

- The size, structure and socioeconomic status of fishing, farming and trading communities dependent, to varying degrees, on the fisheries.

The selection process involved a considerable amount of preparatory work in the form of desk studies and field surveys. Selections were made at four different geographical levels, which are listed below in descending order of size:

1. FAP region
2. Flood control project within FAP regions
3. Aquatic habitats within each project and its control area
4. Sampled sites within each habitat type.

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Four of the five FAP regions were selected for study, i.e. the North Central (NC), North West (NW), North East (NE) and South West (SW) regions. The South East Region could not be studied because of financial, logistical and manpower constraints. Within each region flood control projects were selected to ensure inclusion of a range of types of particular regional significance.

The North Central Region is a relatively unimpacted region with FCD/I projects limited to the compartmentalisation adjacent to Tangail. The FAP regional study FAP 3 medium term plan envisages an embankment along the Dhaleswari-Kaliganga from Pungli to the Bangshi River and further embankment along the Bangshi River. FAP 17 site selection in the North Central Region was designed so that the impact of these proposed constructions could be predicted.

In the North West the FAP 17 study area had been chosen to investigate the Pabna Irrigation and Rural Development Project, which is an example of a recently completed major and extensive embankment project that embanks the confluence of the Jamuna and Padma rivers.

The engineering projects in the North East Region are more representative of the compartmentalization approach to flood control. The North East Region is more susceptible to flash flooding than other regions of the country and represents a rich and diverse fishery. The FCD/I projects in the North East control floods over smaller areas than the major river embankments. In the North East the compartments are either surrounded by full embankments or submersible embankments. The FAP 17 study area in the North East had representative compartments of both full and submersible embankments as well as a completed river embankment project.

The Project areas in the South West Region were selected to investigate the compact compartmental FCD/I projects in the low lying Gopalganj area. Brackish water areas were not included in the sampling programme due to lack of resources.

3.2 Criteria for Site Selection

Regional field stations were established in the Tangail (Manikganj in case of socioeconomic study), Baghabari, Srimongal and Madaripur districts in the North Central, North West, North East and South West regions respectively. The selection of these areas was based on the range of FCD/I projects present in each area and the future planned FAP interventions. From the above field stations a substantial number of fisheries and socioeconomic sampling sites were established, using the set of identification criteria given below.

The central focus of the study was the development of guidelines for the evaluation of impact of FCD/I interventions proposed under the different regional plans developed under the FAP. Paired fishery habitat sites had therefore to be chosen inside and outside existing FCD/I projects. (The outside sites were sufficiently far from FCD/I interventions so that their flooding regime is largely unaffected.) This allowed both an estimation of the differences in fish production that has resulted from past flood control and identification of a set of criteria for future impacts assessment. Differences in fish production must be attributable to the FCD/I; since the data on past catches are both limited and unreliable, pairing has to reflect estimates of pre-FCD/I fishery potential.

Secondly, the significance of incomes from fishing and the importance of fish in rural diets can only be assessed in the context of the other activities in which households are engaged. If an FCD/I results in increased opportunities for crop production or employment for a particular household group, their seasonal loss of fishing income may be less important. But comparisons of income accruing to different household groups in villages associated with the paired fishery habitats are valid as a means of judging FCD/I impacts only if the agricultural potential in the absence of FCD/I was otherwise similar. Fortunately, there is a significant degree of convergence between the parameters that, as a first approximation, define similarities in potential for both fisheries and agriculture: both can be seen as a product of flood duration and depth. To ensure a match in terms of agricultural potential, similarity of soil quality is also desirable.

The District Reconnaissance Soil Survey Reports (RSSRs) which have been consolidated (with a little updating) into the Land Resources Appraisal of Bangladesh, provided the basis for the initial pairing of habitat sites inside and outside FCD/I projects taking into account flood depths and to a lesser extent, flood duration. The RSSR reports were largely compiled in the 1960s and 1970s, and changes will have taken place near the major rivers. But most of the areal extent of the floodplain is relatively stable and the RSSR descriptions can largely be relied upon. Even in the active floodplain, where soil distribution is often highly dynamic, the RSSRs' descriptions have much continuing relevance because their mapping unit was not the individual soil series, but the soil association.

Soil associations - now referred to in the LRA as agro-ecological units (AEUs) - are groups of soils that are commonly found together in a landscape. The LRA provides information on the distribution of soil types within each AEU and on the depth to which that soil is normally flooded. Ideally sites inside and outside FCD/Is were matched by AEUs, as this provided not only similar flooding regimes (unprotected) but similar land quality. Where sites could not be matched by AEU, AEUs with comparable land types and general land use/land capability classifications were used.

Other parameters were also important in establishing sample sites. For instance, the source of flood water is critical for fisheries. Site selection therefore took into account the various drainage basin configurations within the project area. Further hydrographic information was considered by reference to Mike 11, the data and application software developed through the Surface Water Simulation modelling programme set up by the Master Plan Organisation.

3.3 Methodology for Site Selection

Following the selection of a project, the sampling procedure common to both fisheries assessment and socioeconomic studies was as follows:

- Identifying the range of historic flood inundations within the project based on hydrological reports and information provided by the AEU data set.

- Listing the river systems within these regions, superimposing the information on flood origin for each river.

- Identifying suitable comparison areas outside the FCD/I which match the areas in terms of flood depth, duration and origin, again based on hydrological information and AEU. This gave a list of possible pairs of rivers in a range of flood inundations.

- Visiting this set of rivers to validate the data provided by hydrological reports and the AEUs and to assess the feasibility of sampling in that area.

In cases where there was more than one choice of comparison within each classification of flood inundation, random selection was carried out.

Moreover, it was essential to ensure statistically valid non-biased site selection so as to allow extrapolation for the area or population that was sampled and both the construction of fisheries production and socioeconomic models. This was pursued keeping in mind that each site must be within a time limit of 1.5 hour's travel from the field station or sub-station and each must be accessible throughout the year.

3.3.1 Fisheries site selection

The fisheries site selection programme was ecosystem-based and needed to follow the movement of fish from the main rivers through different habitats to the floodplains. The strategy was to sample clusters of sites, following the water connections from main rivers through secondary rivers and canals, to floodplains and *beel*. There were a number of reasons for this approach, predominantly that it allowed study of the migration of fish between habitats and thus a greater understanding of the floodplain system, which in turn allowed an assessment of the fisheries production potential that moves from the floodplain with the migration of fish during the drawdown period.

This prompted the division of the aquatic ecosystem into five types of habitat:

1. Main rivers : Jamuna and Padma (Meghna not studied)
2. Secondary rivers : smaller rivers of varying catchment area, length and discharge
3. Canals : linking rivers with floodplain
4. Floodplain : seasonally flooded land
5. *Beel* : perennial water bodies on floodplain.

Household ponds were not investigated in the present study. However, in areas of regular, deep flooding these multiple use ponds, which often become submerged, can act as dry season reservoirs of fish which are exploited at subsistence level. Ponds (*kua*) specifically excavated on floodplains to capture wild fish were monitored as part of dry season floodplain surveys.

The Jamuna and Padma rivers were surveyed largely independently of regional land-based surveys of flood control projects. All other aquatic habitats, if they occurred within a selected project and its outside control area, were sampled at the same time. The distinction between floodplain and *beel* was fairly arbitrary during the flood season when both were submerged. Most perennial water bodies sampled were small and therefore within these *beel* sites an area of surrounding floodplain was also included.

The final level of selection was that at site level. In the selection of floodplain and *beel* sites inside and outside flood control projects, areas were chosen as far as possible within the same agro-ecological unit, with the same historical flooding patterns and at the same range of land elevation. Wherever possible attempts were made to apply stratified random selection of sampling sites within the logistical constraints of the survey programme. The selection of floodplain and *beel* sites automatically determined the selection of canals and secondary rivers which linked with these areas. Close spatial linkage between different types of habitat was needed to examine possible fish movements through the aquatic ecosystem and identify blockage to movements by flood control structures.

3.3.2 Socioeconomic site selection

The identification of feasible FCD/I projects was carried out in coordination with the fisheries assessment team. The only existing flood control project in the North Central Region was the Tangail CPP. As this small area had already been studied in very considerable detail by FAP 20 and FAP 16, it was felt that respondent fatigue would preclude any further monitoring there by FAP 17. Instead Manikganj was selected and surveyed. Elsewhere the choice of projects was similar to that for the fisheries studies: in the North West studies included Pabna Irrigation Project and Chalan *Beel* Polder B; in the North East, Kai Project and Manu Irrigation Project, and in the South West, Satla-Bagda Polder 1 and Chatla-Fukurhati project.

For the socioeconomic study, the basis used for finding comparable communities inside and outside FCD/I projects was to identify areas of comparable or identical agro-ecological units (AEUs) which occur both inside and outside. These (agro-ecological) units provide an acceptable definition of the distribution of historical flooding regimes, in conjunction with the distribution of soil types, over discrete areas. Taken together, these factors provide the principal indicators of agricultural potential for any particular area in Bangladesh. This in turn will provide the best indicator, available for the entire country, of the agricultural production level of communities located within those AEUs and thus give a basis for the initial selection of areas inside and outside FCD/I where, historically, communities with broadly similar agro-economic characteristics could be found.

Within the areas of a particular AEU identified, up to 5 blocks were defined using the 1:50,000 maps from the Survey of Bangladesh. These blocks were selected so as to be of consistent sizes; 3 X 3 grid squares or 3 kms X 3 kms on the ground and were completely within areas covered by the AEU in question. Inevitably there were some cases where small areas of the periphery of these blocks fell on to different adjacent AEUs, but these cases were kept to a minimum. In the definition of blocks, practical and logistical considerations and accessibility were borne in mind.

For each AEU area 5 separate blocks were identified so as to have a greater range from which to carry out the random sampling process. On some AEUs, it was not possible to identify 5 blocks due to the restricted dimensions of the AEU area or problems of inaccessibility. In these cases, as many blocks as are practicable were identified for sampling. A block was then selected by simple random sampling using random number tables. This sampling procedure was continued until all the blocks within a particular AEU had been placed in order.

The *mauza* falling within each block was then identified using the 1:50,000 maps in conjunction with the Small Areas Atlas of Bangladesh published by the Bangladesh Bureau of Statistics. Each *mauza* within a certain block was assigned a value equivalent to the number of households in the *mauza* as listed in the Small Areas Atlas. This provided a means of weighting the *mauza* sampling procedure to account for size of communities. These values for the *mauza* was then listed cumulatively and all the *mauza* within each block were assigned an order number, again using simple random sampling and random number tables.

Starting with the first selected block of a particular AEU, all the villages within that particular block were then visited by an appraisal team. The villages were visited in the order established by the second stage random sampling process.

These appraisals had the following objectives:

- Identifying *mauza* or villages making up *mauza* with a distribution of land types and flooding depths which correspond, within acceptable limits of accuracy, to the general distribution defined for that AEU in the FAO Land Resource Survey of Bangladesh.

- Identifying any socioeconomic factors in particular areas or *mauza* which might distort the representativeness of those communities for the purposes of the FAP 17 socioeconomic study eg. appreciable daily labour opportunities in nearby towns or industries or high levels of NGO activity.

Appraisals were continued through the *mauza* in a particular block, in order, until 6 villages corresponding to the AEU "standard" had been identified. If a suitable number could not be identified on the first block, the search was shifted to the second block using the same approach.

From the 6 villages identified as representative of a particular AEU, one was then selected as a target village for the socioeconomic survey using simple random sampling. Selection of fishing communities was carried out in a consistent and representative manner to ensure that these were identified in the vicinity of the main sample villages which interact in some way with the people of those main villages. This approach guaranteed that the fishing communities selected would be more easily accessible and provide the opportunity to understand fisheries in a particular rural setting in more detail.

However, this procedure was able to keep constant only those features of the community resource base that affect agricultural livelihood strategies at a macro level. In practice, levels and patterns of income were also significantly influenced by numerous micro level variations in factors such as land holding patterns; proximity of sources of alternative livelihood opportunities; NGO activity, and *jalmahal* control etc. Indeed the effect of these factors was sufficiently strong to rule out any hope of measuring flood control impacts through community comparisons.

4 SAMPLING METHODS

Methods used in fisheries surveys were described in detail in the Interim Report of FAP 17. In addition, a brief summary of these were presented in the Main Volume of the Final Report. A detailed description of both fisheries and socioeconomic sampling methods are presented in this section.

4.1 Fisheries Sampling Methods

4.1.1 Fish production study

The term fish production here refers to the total fish catch or yield from different types of fishing gears encountered during the study, not biological productivity. The aim of the production study was to provide quantitative estimates of fish catch by species of all gears operating on floodplains, *beel*, canals and rivers. This was achieved by the use of two types of survey: a catch assessment survey (CAS), which measured the catch rate of each gear type, and a fishing effort survey (FES) to estimate fishing effort in terms of number of units and duration of fishing by each gear type operating day and night.

The FES and CAS were carried out on the same day so that for gear types that counted catch rates could be obtained. Initially the surveys were conducted on different days (as this was a more efficient use of manpower). This led to some problems in the calculation of production as gears were not always operating on both days. By carrying out CAS and FES surveys on the same day, closer matching was achieved.

All sites were surveyed for two days per month enabling gears not monitored on the first survey day to be recorded on the second survey day. Use of the CAS/CAS10a allows the Senior Fisheries Supervisors to keep stock of the missing gears from the first survey day and attempt to get catch rates for them on the second day.

Both surveys were carried out in the demarcated area of the site. Site boundary markers such as mosques, village boundaries, distinctive trees, electric pylons, roads and bridges are known to all field staff and documented on sketch maps of each site.

The Fisheries Biologist carrying out the FES counted and recorded the number of fishing

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gears operating during six two hour periods from 0600 hours to 1800 hours. Fishing gears were pre-coded at the start of the sampling programme and adjusted as more information about fishing gears and usage was gathered. In addition, information concerning the number of hours fished in the day and night was collected on form FE02. Usually one Fisheries Biologist completed the FES.

The CAS required two Fisheries Biologists, one to sort and identify fish and the other to interview the fisherman. The monitoring of one catch took approximately 15 minutes, as any longer would disturb relationships with fishermen, who took time out of their fishing activities to talk to the field officers. The Fisheries Biologists carried out about 15 interviews per day. Where a large number of fishing gears were operating at a site, the catches of at least three gears of each type were monitored. On occasions when the fishing activity was high, less common gears were favoured for CAS. The catch rates of more common gears like *thella jal* (push net) could be obtained if time were available; alternatively, this could be accomplished on the second survey day of the month. This allowed catch rates to be obtained for most of the gears operating in Bangladesh. If catch rates were not obtained during one month, they were estimated from data collected during the surveys a month before or a month after.

These data were then processed to obtain an estimate of the total monthly catch of each species within each site. Monthly catch estimates were then converted to weight per unit area of floodplain or *beel* and per unit length of river and canal. Catches from rivers and canals were expressed as kg/ha or kg/km. Values of catch per unit area or catch per kilometre were then used to compare the same type of aquatic habitat i.e. floodplain, *beel*, canal, and river inside and outside areas of flood control. To compare catch estimates from larger areas inside and outside projects it was necessary first to extrapolate catch estimates from site level to these larger areas. On floodplains this was done by using area elevation curves of extrapolation areas and by applying catch rates from sites within a defined range of land elevation to appropriate areas obtained from the area elevation curve. For canals and rivers, total lengths were estimated within the extrapolation area and catch rates (kg/km) were applied to these to obtain total riverine and canal catches. These were then added to the total floodplain/*beel* catch to obtain the total catch from the extrapolation area which, when divided by its own area, provided an estimate of the integrated catch per unit area of floodplain. These estimates were than used for comparison between areas inside and outside FCD/I projects.

Processed data of catch and catch rates were considered for specific implications and statistical analyses. These are briefly described in the following sub sections. Detailed description of statistical analyses employed as part of impact assessment procedure is presented in Section 6.

4.1.1.1 Fish densities

Statistical analyses of seasonally pooled catch rates of dominant gears used inside and outside flood control projects were undertaken. The underlying assumption of the method was that, once differences in catchabilities between gears had been accounted for, any further differences in catch rates inside and outside FCD/I projects were due solely to differences in fish densities.

4.1.1.2 Fishing effort

The model used in the statistical analysis of catch rates provided a standardisation of effort between different gears. The estimates of standardised gear effort in terms of gears hours of the selected standard gear were then used to compare sites inside and outside projects. In cases where the statistical model could not be fitted, comparisons were made of the effort by individual dominant gears in and out of FCD/Is.

4.1.1.3 Biodiversity

The term "species diversity" was used in its simplest sense to denote the total number of different species of fish recorded at each site. The number of species recorded depended on the sampling effort deployed. No doubt more species would have been recorded had more sites or gear units been sampled more often using larger sub-samples of catches.

4.1.1.4 Catch composition

Determination of monthly and annual percentage catch compositions by weight were used to assess the impact of flood control on fish community structure and, in particular, to evaluate the impact on migratory species. All species recorded were divided into three categories of habitat preference: riverine, migratory and floodplain-resident, based on distributions identified using the complete FAP 17 database. The categorisations should be regarded as provisional only. As more knowledge is gained of the ecology and behaviour of individual fish and prawn species in Bangladesh, more accurate revisions to the list will be required.

4.1.2 Fish movement study

4.1.2.1 Adult and juveniles

Seasonal movements of adult and juvenile fish between spatially linked sites in different habitats were identified from changes in monthly catch compositions; temporal and spatial changes in the distributions of important individual species, and changes in monthly species numbers and catch contributions of riverine, migratory and floodplain resident fish. Where available, additional information on the average size (weight) of fish and their reproductive state were used to determine whether fish were adults or juveniles and whether movements were primarily for growth, breeding or both.

4.1.2.2 Hatchling study

Investigations of downstream passive drift of fish hatchlings were carried out in all regions except the South West. The studies involved the collection of fish larvae in surface set drift nets of known area over measured time intervals and measured water velocities to provide quantitative estimates of supply rates and densities of different fish species under varying flow conditions. This information could then be used to assess the impact of flood control embankments on fish movement at a critical stage of their life cycle prior to recruitment into subsistence and commercial fisheries. The results also assisted in the formulation of proposed mitigation measures by improvements in regulator design and operation to allow the passage of hatchlings on to their nursery grounds on floodplains.

More detailed descriptions of sampling methodology has been included in the Supporting Volume No. 11 of the Draft Final Report.

4.1.3 Population dynamics

Population dynamics studies were designed to supplement the main fish production studies by providing biological explanations for differences in catch inside and outside FCD/I projects in terms of growth, mortality, recruitment or exploitation of selected fish populations. The study was based on fish stock assessment techniques using computerised length frequency analyses on a limited number of species representing different trophic levels and exhibiting different breeding behaviour.

During the Catch Assessment Survey, a sample of fish was collected, stored on ice and then taken to the laboratories at regional field stations. Measurements of standard lengths of the "model" species were carried out in the laboratory in order not to delay fishermen unnecessarily. These "model" species are listed in Table 4.1.

The lengths (total length** and standard length*** for the first 100 fish and thereafter just standard length) were measured and the larger (at least 20 from each site per month) were dissected to establish the reproductive condition of the fish. The least selective gears, such as seine nets, were chosen for the collection of samples for length. Fish were also collected from a number of other gears like cast nets, push nets and lift nets, which are very common, because seasonally employed gears such as seine nets will not give data over a sufficient time period.

Length data from fish caught in different gears was kept separate until the selectivity of each were considered. Selectivity was assessed for the most common gears such as lift nets and push nets.

The time period per month over which length frequency data was collected on the "model" species has been minimised to ensure a distinct sampling period. However, if the growth of fish at a particular time of year was very low, so that there would be little progression in the modal length class due to growth, then samples from two separate months were pooled. It was possible to collect samples for length frequency analysis from all the sites in a region over a period of eleven days. Since many of the fish measured may have been young or even fry and have rapid growth rates, it was considered advisable to reduce this period as much as possible. Reducing the time of data collection to about four days meant that key sites had to be selected in each region. This had the consequence of increasing the number of individuals needed from each catch. The sites from which fish are collected for length

** Total length is the length of the fish from the tip of the snout to the end of the tail.

*** Standard length is the length of the fish from the tip of the snout to the end of the caudal peduncle (where the tail fin starts).

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Table 4.1 "Model" species for studies of population dynamics

Scientific name	Bengali name
Aspidoparia morar	*Piali*
Nemacheilus botia	*Balichata*
Botia dario	*Rani*
Corica soborna	*Kachki*
Clupisoma garua	*Ghaura*
Gagata youssoufi	*Gang tengra*
Mystus bleekeri	*Golsha tengra*
Mystus cavasius	*Kabashi*
Salmostoma phulo	*Fulchela*
Gudusia chapra	*Chapila*
Eutropiichthys vacha	*Bacha*
Wallagu attu	*Boal*
Anabas testudineus	*Koi*
Mystus tengara	*Bajari tengra*
Mystus vittatus	*Tengra*
Colisa fasciatus	*Khalisha*
Xenentodon cancila	*Kaikka*
Osteobrama cotio cotio	*Keti*
Puntius conchonius	*Canchan puti*
Puntius sophore	*Puti*
Puntius ticto	*Tit puti*
Amblypharyngodon microlepis	*Mola*
Glossogobius giurus	*Bailla*
Lepidocephalus guntea	*Gutum*
Channa punctatus	*Taki*
Heteropneustes fossilis	*Shingi*
Macrognathus pancalus	*Guchi*
Mastacembelus armatus	*Baral baim*
Chanda nama	*Nama chanda*
Chanda ranga	*Lal chanda*

frequency analysis are given in Table 4.2.

The analysis of length frequency data was not dependent upon having large monthly samples throughout the sampling period, but was used with samples more than one month apart, as long as each reflected the status of the population at that time. This means that poor data were discounted. The collection of length data through the dry season was sporadic, in that fishing activity was reduced and a number of sites previously sampled were dry. The collection of data from *katha* and *kua* however was very important. The catches from *katha* and *kua* were much greater and provided an opportunity to collect substantial data.

Table 4.2 Sites considered for length frequency and reproduction studies

Region	North West		North Central		North East			
Project	PIP		CPP		MIP		SHP	
Position	In	Out	In	Out	In	Out	In	Out
Grouping of sites for comparison of data	NW03 NW04 NW05 NW06 NW07	NW02 NW14 NW15 NW16 NW17 NW18	NC10 NC11	NC02 NC03 NC04 NC05	NE01 NE02 NE03 NE04 NE05	NE06 NE07 NE08 NE09 NE10	NE12 NE13 NE14 NE15	NE16 NE11 NE17 NE18 NE19 NE20
Grouping of sites for comparison of data	NW08 NW09 NW10	NW01 NW19 NW20 NW21	NC12 NC13 NC14 NC15	NC06 NC07 NC08 NC09				
Grouping of sites for comparison of data	NW11 NW12 NW13	NW24 NW25 NW26		NC16 NC17 NC18 NC19				

Note: PIP - Pabna Irrigation Project
CB(Pol B) - Chalan *Beel* (Polder B)
CPP - Compartmentalization Pilot Project (Tangail)
MIP - Manu Irrigation Project
SHP - Shanghair *Haor* Project

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4.1.4 Fish disease study

During CAS the fish were examined for signs of Epizootic Ulcerative Syndrome (EUS) and the number and species affected were recorded in form DE01. The incidence of the disease might be affected by flood control. This information is also of general interest for Bangladesh and other countries in the region.

4.1.5 Water quality and hydrology

In order to carry out an assessment of the impact of flood control on fisheries, it was essential to relate the information on fish stocks collected by the methods described in the previous paragraphs to changes in the timing, extent, duration and magnitude of flooding. Unfortunately, it is precisely this type of detailed hydrological information which is lacking for Bangladesh. To provide baseline data on flooding patterns at floodplain sampling sites, therefore, biologists undertaking fortnightly FES surveys also collected data on the flood extent using sketch maps and measured water depths at fixed points on the floodplain covering a range of land heights. These consisted of determination of water depth, transparency, temperature, conductivity, total dissolved solids concentration, pH and dissolved oxygen. These are aspects of water quality which, when considered together, provide a useful description of factors important for fish.

4.2 Socioeconomic Sampling Methods

The socioeconomic analyses are based principally on data derived from the fish catch assessment survey (FCA) conducted by the fisheries team of FAP 17, and the socioeconomic household monitoring surveys, conducted by the socioeconomic team. In addition, information has been used from a series of *ad hoc* surveys on issues such as fisheries access and fish marketing. The methodology used for the socioeconomic surveys were previously described in the Interim Report of FAP 17.

4.2.1 Impact assessment

The original design of the socioeconomic study placed the entire burden of estimating flood control impact on inside-outside comparisons of villages. It was assumed that a proper pairing of pre-FCDI agroecological conditions would be sufficient to ascribe differences to

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the effects of flood control. It was recognised that there might be "distorting factors" that might cloud the interpretation, such as unusually intensive levels of irrigation or NGO activity; hence the need for the supplementary information gathered during land type appraisals that would allow some check on this. But these "distortions" were to sources of income other than that from fisheries; to the background not the foreground of the study.

As noted in the Interim Report of FAP17, the experience on the RRAs made it apparent that there were also localised factors capable of significantly "distorting" the flow of fisheries benefits, even to the point where a fisheries resource of national significance might have almost no value to many of the local communities. Leaseholders' exclusion of local fishermen from the important "mother fishery" of Hakaluki *Haor* in Sylhet is one example of this.

As this diversity of circumstance invalidated the measurement of impacts through paired comparisons, an alternative procedure was devised. The impacts of flood control on fisheries livelihoods was estimated using the results of the catch assessment studies as a starting point. The price data gathered in the marketing study was used to translate changes in catch per unit area and changes in flooded area inside and outside FCD/Is into changes in gross fisheries incomes. This was then divided between professional and subsistence fishermen, using the data on gear ownership and use from the socioeconomic census and the catch assessment questionnaire.

Changes in net income to fishermen (both subsistence and professional) was calculated by deducting their payments to leaseholders (derived from the Access Survey) and costs of gear operation - gear maintenance and debt servicing - derived from the special studies. This gave a picture of changes in aggregate incomes in different regions or sub-regions (depending on the level of extrapolation that seems reasonable) due to FCD/I interventions.

These figures were then placed in the context of the more detailed information obtained at the household level by the village studies. This linking of the estimates of fishing income derived from manipulation of the fish catch assessment data with direct estimates was critical but it allowed to place fishing incomes in the context of the other sources of income.

4.2.2 Village census

A census survey of all the households in the main agricultural villages and the fishing households in the fishing villages gathered information on numbers of family members, education and age of household head, principal sources of household income, fishing involvement and ownership of land, ponds, fishing gears and boats.

To assist with the monitoring, each household was classified according to its landholding and involvement in fishing. This allowed the sample to be stratified, so that the monitoring effort could be focused towards households for whom fishing was an important activity. Non-fishing households were also covered, to provide a basis for comparison.

The standard BBS landholding categories were used: large landowners were defined as those owning 7.5 acres or more; medium landowners as those owning 2.5-7.5 acres; small landowners as those owning 0.5-2.5 acres, and landless as those owning less than 0.5 acres.

Table 4.3 Household fishing categories

Household fishing category	Criteria
HFC1	No other major source of income ranked
HFC2	Primary source of income - other sources ranked
HFC3	Other sources of income ranked higher than fishing
HFC4	Fishing primarily for subsistence - not ranked as a source of income

The possibility of simply adopting the traditional fishing categories of professional, part-time and subsistence fishermen was considered but rejected as too crude. The principal problem was with the heterogeneity of professional fishermen, who can vary from large fishing entrepreneurs owning a number of boats and numerous gears, to simple fishing labourers who do not even own a push net. There were also difficulties with the distinction between subsistence and part-time fishermen, however. As a result, households were divided into fishing categories determined by gear ownership, gear investment and the number of months in which income was obtained from fishing. These are defined in Table 4.3.

4.2.3 Household baseline survey

A simple pre-coded questionnaire was developed to collect information on the present position of the respondents in terms of family composition, education, employment and occupation, migration history, land type, use, and ownership status. Information was also gathered on ownership of assets - such as agricultural equipment, livestock, transport etc. - and on poverty indicators e.g. food deficit months, clothing and indebtedness periods.

4.2.4 Household monitoring

Household monitoring of all the baseline survey respondents was then carried out, through repeat surveys over one year (1993-94) covering the Bengali months *Magh* (January-February) to *Poush* (December-January).

The principal focus of this survey was on household livelihood strategies, to gain a greater understanding of the sources and magnitude of income flows (in both cash and kind) into and out of the household through the year, so that the significance of the contribution of fisheries could be gauged more accurately. Accordingly, monthly information was gathered on income, expenditure and labour absorption of eleven different categories of enterprise: agricultural; livestock; agricultural labour; non-agricultural labour; food-for-work; self-employment; gear making; fish trading; fishing; fish culture, and expenditure saving activities. Of these, the four that relate to fishing are being covered in detail, with summary data being collected on the rest. These eleven categories are described in Table 4.4.

To understand seasonal variations in the dietary importance of fish for different socioeconomic groups, food consumption was monitored. A questionnaire was developed, which was administered by the female research assistants to the female members of target households on the composition of meals over the previous 48 hours. Particular attention was paid to fish and details sought on where fish was obtained and whether it was bought or caught. In addition, information on the frequency of fish consumption over the previous week was obtained.

This monitoring of food consumption gave information about the actual nutritional significance of fish. It also provided a clearer idea of the relative importance of fish compared to other food stuffs.

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Table 4.4 Enterprise types covered in monitoring

Code	Enterprise type	Activities
AE	Agriculture	Income earning crops, vegetables, fruits, trees and forest bushes are included in this category. Thirty-five enterprises pre-coded.
LV	Livestock	Income earning poultry birds and domestic animals are included in this category. Three enterprises.
AL	Agricultural labour	Agricultural labour covers man-days spent and income earned from providing labour for farm activities to others. This includes labour on daily, contract or exchange basis.
NL	Non-agricultural labour	All labour used for non-agricultural purposes either on daily, contract or volume basis. Services in government/NGO/private organizations are included in this category.
FW	Food for Work	Infrastructural works such as earth work, embankment construction or repair, roadside tree plantation work etc. is often sponsored by the government, who pay the labourers in food (mostly wheat). These are important sources of income for the poorest households at some times of the year.
SE	Self Employment	Skilled labour: carpenter, potter, blacksmith, goldsmith etc. and transport labour, as well as professionals like doctor, teacher, engineer, lawyer etc. and trade and business.
GM	Gear making	Making and maintenance of fishing gear is included in this category. Gear making for both commercial and household uses is included.
FT	Fish Trading	Different types of fish traders are included in this category. Activities related to each type of fish trader are considered as separate enterprise. Four enterprises.
FE	Fishing	Income received from fishing by different types of gears are included in this category, with each gear type considered a different enterprise.
FC	Fish Culture	Income and activities related to fish culture in pond, ditches, etc. are included in this category. Four enterprises.
ES	Expenditure Saving	Activities which do not earn cash income directly but play an important role in the households' livelihood are included in this category: post harvest operations; food processing; gleaning; fuel collection; grazing etc. Fifteen enterprises.

4.2.5 Rapid rural appraisal

The study methodology outlined above was intended to quantify incomes and time-use to assess the seasonal importance of fisheries relative to other livelihood strategies of different socioeconomic groups. A more open-ended approach to research was needed to understand many of the factors that might explain these variations: social and political factors influencing access to leased water bodies; the historical changes in fishing communities, and their perceptions of fisheries resources.

The principle research goals for the Rapid Rural Appraisals (RRA) were to:-

- Understand the historical and seasonal factors influencing water and resources in the target areas.

- Identify uses of water bodies and conflicts over water body use.

- Identify social and occupational groups and their relative involvement in fisheries.

- Understand local people's perceptions of flood and flood control measures and their impacts on fisheries.

- Understand women's participation in fisheries and other rural enterprises.

- Clarify the goals and activities of the study to local people and, as far as possible, ensure their participation in the subsequent survey and monitoring activities of the project.

RRAs were conducted as follows:-

Step 1 A RRA team consisting of socioeconomic consultants, regional supervisor and research assistants of the respective region was formed for each region.

Step 2 The regional supervisor organised a village meeting on the morning of the first day, to which all the villagers, particularly village leaders and members of different socioeconomic groups, were invited. Members of the RRA team addressed the villagers indicating the objectives of RRA and the subsequent studies which were to follow in the village.

Step 3 After the meeting, members of the team were divided into three groups. One group, consisting of female members, was chosen exclusively to interview

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female household members and assess the participation of the women in agriculture, fishing and other enterprises. The other two groups dispersed to interview villagers of different socioeconomic groups.

At this stage, each team prepared a sketch map of the village with the help of the villagers, showing the location of the homesteads of different social, ethnic and economic groups. Key informants and several homogeneous socioeconomic groups were interviewed at this stage. While a general checklist was used, all efforts were made to keep the discussions with the villagers open and frank.

Step 4 All team members met on the evening of the first day to discuss their experiences and identify key issues needing detailed investigation.

Step 5 On the second day, the team members were divided into three groups, each with a particular area of responsibility: fisheries, employment, institutions and marketing and social issues. Historical change, seasonal change and gender roles for each area were investigated.

Step 6 All the team members met in the evening to discuss the findings and identify gaps where more information was needed. The task of writing specific sections of the report was delegated to individual members in this meeting.

Step 7 On the third day, gaps were filled using a checklist to interview key informants. Individual members started writing their assigned part of the report on the same day.

Step 8 All the team members met on the evening of the third day and the individual members presented their reports. After thorough discussion, necessary modifications were made. The contents, maps, charts, graphs etc. needed for the report were listed and finalized at this stage.

4.2.6 Fish marketing and prices study

The Fish Marketing and Prices study is one of the socioeconomic components of FAP 17.

The methodology and data processing has been presented in detail in the Fish Marketing and Prices of the Final Report. The following is an abridged version of the methodology taken from that volume. Section 5 contains the data processing steps.

Information Sources
The Fish Marketing and Prices study used both primary source data and secondary sources of information.

The primary source data consisted of information collected through a survey of sample fish markets and monitoring of fish trading households. Price data collected by the Market Survey provided producers' prices. Detailed information on cost components and returns to capital were collected from primary sources by intensive interviews of "key informants" in selected primary, secondary and tertiary markets. The Village Monitoring Surveys collected detailed information on the role of fish marketing in the livelihood strategies of the sampled fish trading households. Monthly prices of major species were collected from the sample primary markets by regional socioeconomic survey teams.

Secondary sources were used to gather information on production trends, trade flows, credit provisions and marketing institutions. The study also used monthly price data for important wholesale markets that is available from the Directorate of Agricultural Marketing (DAM). Monthly price data on major fish species were collected from DAM for the period from July 1983 to June 1992. Major sources of secondary information are:-

- Department of Fisheries (DoF)
- Bangladesh Bureau of Statistics (BBS) publications
- Directorate of Agricultural Marketing
- Master Plan Organisation (technical reports)
- Reports from FAP 6 and FAP 12
- Rapport Bangladesh Ltd.

Study Areas
The study area is all of Bangladesh. For the convenience of cross-referencing the marketing study with the main socioeconomic study, the same four regional divisions of the country are used: North Central, North East, North West and South West.

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Selection of Sample Markets
The criteria for the selection of sample primary markets were: location near socioeconomic study sample villages, and proximity to fisheries sites. Secondary markets were selected on the basis of their links to Dhaka markets and sample primary markets.

The original plan called for the selection of eight sample markets from each of the four regions: four primary markets; three secondary markets, and one tertiary market. This plan was adhered to in all but the North Central Region where there were not enough secondary markets to satisfy the selection criteria. Because of the proximity of Dhaka, fish from sample primary markets in this region are sent directly to Dhaka wholesale markets. In view of this, three major wholesale markets in Dhaka were included in the survey.

Selection of Key Informants
Key informants were then selected and interviewed at three major wholesale markets. The informants included presidents and secretaries of trade and market associations, leading *aratdar* and other market intermediaries. During this exercise, traders supplying fish to Dhaka wholesale markets were interviewed to identify major link markets.

Key informants for each sample market were identified during visits to the market. Informants were interviewed by administering a checklist to collect basic information on the market with which they were associated.

Selection of Respondents
Traders in wholesale fish markets, with the exception of *aratdar,* do not maintain offices in the market. It is therefore difficult to make any meaningful census of the types of traders operating in a market, so respondents were selected to ensure reasonable representation of various functions in the marketing chain.

The ideal composition of respondents in the primary markets was:

Fisherman	4
Faria	3
Aratdar	3
Nikari	2
Total	**12**

The ideal composition of respondents in secondary and tertiary markets was:

Fisherman	3
Aratdar	3
Bepari	3
Nikari	3
Total	**12**

It was impossible to adhere strictly to these ideals, however, because fish market traders tend to move from market to market.

A total of 249 market intermediaries was interviewed comprising middleman traders (*faria, bepari, paikar* and *chalani*), *aratdar* and *nikari* (retailers). In addition, 103 respondents were interviewed from among the fishermen selling directly to the sample markets.

Information was also collected from 14 transport agencies and 46 ice factories located within 10 km of the sample markets.

Market Survey Procedures

A comprehensive, structured, multiple-visit survey of a large number of primary, secondary, and tertiary markets was beyond the resources of this study. The method used instead intensively interviewed key informants and selected respondents in the designated primary, secondary and tertiary markets during a single visit. The surveys were conducted between June 1993 and March 1994.

The subjects of the survey in each market were interviewed using the structured questionnaires. The interviews were conducted by the study's Research Assistant under the guidance and supervision of the Lead Researcher.

Information on prices, costs and transaction volumes was obtained from records such as vouchers, transaction registers and other records maintained by *aratdar* in each market. Information on quantities of fish traded, prices obtained and costs incurred for trading activities during the preceding peak and lean periods relied on the memories of those interviewed. Information on market characteristics and infrastructure was collected through field observation and by interviews of key informants in each market. The Research Assistant also collected retrospective price data for six months for 16 groups of fish species generally traded in the market. Monthly prices of major species in the sample primary markets were monitored by the regional socioeconomic survey teams.

4.2.7 Fisheries leasing and access study

The Fisheries Leasing and Access study undertaken by FAP 17 as part of its socioeconomic research programme, like those on marketing, was restricted, and for the same reasons. Rather than spreading limited resources too widely in an attempt to cover areas already studied in depth by others, or which are only on the periphery of project interest, primary research was focused on core concerns. In other areas, where information was required as background, secondary sources and the outputs of other recent/current projects - Third Fisheries (WB/ODA); Implementation of New Fisheries Management Policy (Ford Foundation) and Institutional Strengthening in the Fisheries Sector (FAO/UNDP) - were consulted.

The issue of access was approached from several angles. At the highest level, information was collected by the fisheries team on the *jalmahals* that cover their catch assessment sites. If the fishery was leased, the agency responsible for issuing the lease was identified, as well as the leaseholder and his place of residence.

The socioeconomic field team also investigated access to all the water bodies, major and minor, in or adjacent to the main villages already under study. Selected villages were mapped. Where study villages are adjacent to CAS sites, more detailed study was undertaken.

A separate, Dhaka-based team undertook a series of more detailed studies on access restrictions at selected catch assessment sites. RRA techniques were used rather than formal sampling. A variety of questionnaires had been developed which covered the following:-

- Historical evolution of access restrictions and means of enforcement.
- Leaseholder expenditure.
- Terms of access for different gears through the season.

Supporting Volume No. 21 of the Draft Final Report describes fisheries leasing and access in the North East Region. All socioeconomic supporting volumes (Vol No. 12-18) include separate sections on fisheries access for each of the study area.

4.2.8 Target group approaches to pond aquaculture

FAP 17's study of the approaches used by NGOs in Bangladesh for the extension and development of aquaculture, was aimed at assisting in the planning of measures to mitigate the negative effects of flood control on fisheries. The overall objective of the study was to identify past NGO successes in this field and to determine how the approaches used might be adapted or developed to help mitigate the impact of the FAP.

The specific objectives were to:-

- Review past initiatives by NGOs in the development of aquaculture for targeted groups.
- Identify the most appropriate models for the development of aquaculture by NGOs for the benefit of the target groups.
- Assess the availability of the resources necessary to promote TGAs on the scale necessary.

The findings of the FAP 17 study of target group approaches to aquaculture development have been produced as two reports. The baseline study of NGO fisheries was previously documented as Annex C of the Interim Report and has been reissued as Draft Final Report, Supporting Volume No. 25. From this baseline study six NGOs were selected for further intensive study on NGO group approaches to pond fisheries development. This has been presented in Draft Final Report, Supporting Volume No. 22.

The sample frame for the survey was a list produced by the ADAB of 107 NGOs involved in the development of fisheries. While this list was not exhaustive, covering only those qualified to be members of ADAB, nearly all the more important NGOs were included. These agencies were categorized as 'locals' (those working within a limited geographic area within Bangladesh); 'national' (those working throughout Bangladesh); and 'international' (those working in Bangladesh and other countries and managed by foreign personnel).

The criteria for the inclusion of NGOs in the study were devised on the basis of consultation with IVS-ADAB personnel working in the fisheries sector, and with ICLARM, an

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international research centre specialising in aquatic resource management. These were:-

- Length of involvement in fisheries.
- Type of beneficiaries.
- Linkage-coordination with ADAB.
- Primarily involved with pond aquaculture.

Twenty one NGOs were selected for study. The sample represents 20 percent of the total NGOs working within the fisheries sector in Bangladesh. Each organisation completed a simple structured and semi-structured questionnaire.

These NGOs were then studied to determine: the nature of their participation; the length of their fishery programmes; the nature of those programmes; their approaches to fish culture; the personnel involved in their programmes; the ratio of target groups to field workers, and problems encountered with the groups or their pond fisheries. From this process six NGOs were identified for further study.

5 DATA PROCESSING

The structure and description of all databases has been presented in Appendix 1 and 2 of the Draft Final Report for fisheries and socioeconomic study respectively. In Section 5 and 6, file and field names have been used. Appendix 1 and 2 will provide clearer understanding of these names.

5.1 Processing of Fisheries Data

5.1.1 Fish production - all gears except FADs

Catch Rates

Catch rates were computed using the data from CAS. Catch details of the subsamples stored in the CAO3_S4.DBF file were first raised by applying the conversion factor:

$$\frac{\text{Total catch of all species-total catch of individual fish on CAO3\_S2}}{\text{Total of subsample catches on CAO3\_S4}}$$

The total catch from a particular species, gear and month was then summed from the records on files CAO2.DBF, CAO3_S2.DBF and CAO3_S4.DBF. This was divided by the total hours fished to achieve that catch. The information is recorded on the CAO1.DBF records for the same gear and month. For gear types 97, 98 and 307 the number of gear hours was defined as the total hours fished multiplied by the number of people fishing. For other gear types, gear hours were defined as the total number of hours fished multiplied by the number of gears used.

For each gear the sum of the species catch rates equals the catch rate for the gear type.

Day Effort

The measure of total effort was separated into day and night. On a number of occasions the survey team was not able to complete the first or last survey of the day. As these are particularly important when assessing night effort they were estimated by duplicating the corresponding 1000 and 1600 surveys where they exist. For a small number of surveys it was considered more appropriate to create infilled records on a judgemental basis.

FEO1.DBF records the results of counting different gear types at a site and location in two hourly intervals between 0800 and 1800 hours. Between April and September daytime was treated as 0500 to 1900, and for the rest of the year it was 0500 to 1800. Gear counts for the early morning hour were calculated as 0.5 the first survey of the day while during the summer months the last hour was estimated as 0.5 of the last survey count. At the same time all gear counts were multiplied by 2 in order to calculate gear hours.

The average daily total of gear hours was then calculated for each gear type, month and site combination, taking into account data from all surveys in the month for that site. This figure was multiplied by the number of days in the month to provide total day effort by site, location and gear.

Night Effort

One question asked on the FEO2 form was whether a particular gear was being used for night fishing for a particular site and month. As no night gear counts were taken during the FEO1 survey, the first and last of the daily FEO1 surveys were used to give an estimated night count for these gears. The number of hours fished was then calculated from the CAO1 form by splitting the fishing hours into day and night.

Monthly night gear hours =

$$\frac{\text{Total daily average gear count * Average CAO1 night hours * days in month}}{\text{Number of FEO1 surveys in the month}}$$

Some gears, traps in particular, were considered to fish all night. In these cases the number of hours fished each night defaulted to 11 or 10 (winter/summer).

In mid 1993 additional evening visits were made to sites to supplement catch rate data and to count the number of gears in operation. The additional data is stored in NFGEARS.DBF. Where night fishing is identified in CAS but no gear count is available from FES the supplementary data was used to provide a count of fishing effort.

Main River Effort

The main river sites were surveyed using a launch HML Otter. It was not possible to conduct 2hr surveys on a precise basis. Instead the actual time of each survey was recorded and data stored in FEO1OTT. This file was used in much the same way as FEO1 to provide estimates of gear counts.

Total Catch
Multiplication of total monthly hours of effort by the catch rate for each gear/month/site yields the total catch. Total catch and total effort were divided by the actual site area in order to express results in a suitable form for comparison. The chosen units are kg/ha for *beel*/floodplains and kg/km for canals and rivers.

The processed data was then expressed in various ways to allow interpretation of results and description of the fishery. These were also loaded into a software package written in RBASE programming package to allow graphical presentation of results.

Processing Interventions
While processing broadly followed the steps described above a series of interventions was developed to deal with unusual problems. These major anomalies are described below.

- Where gear counts exits from FES but no catch rate was available from CAS, other catch rates were infilled from adjacent sites in the same month or from adjacent months for the same site. Where catch rates exist without gear counts these were ignored.

- Abnormalities sometimes occurred in estimates of production. For example an unusual catch of 1 large fish in a trap could artificially inflate estimates of production. In such cases documented manual interventions were used to adjust catch.

- Physical conditions such as partial flooding or failure to provide logistical support sometimes upset the survey schedules. Sites were often split into smaller units called locations to provide more precise detail. A routine monthly schedule report was kept in all regions to record which sites/locations were visited, when, whether there was fishing activity or not, and what surveys were successfully completed. Details of this schedule were entered into a file MON_SCH.DBF and used to deal with the problems of ensuring that the calculations in the computer matched the actual field visits.

- In the North East Region during January and February 1994 leaseholder activities were observed. During this period monitoring was very high - daily in some cases - and the leaseholder activities have been processed using different routines.

- *Katha* (brush pile) fisheries and *kua* (fishing pits) also presented particular problems. In both cases counts of the number of *katha* and *kua* in each site were necessary. Since harvesting these gears frequently takes more than 1 day the FES/CAS sampling schedule was unable to account fully for these methods of fishing. Additional, more intensive, surveys were undertaken with supplementary documentation to provide the data required. Processing steps were also different.

5.1.2 Fish production - FADs

For some fishing gears in Bangladesh it has been necessary to provide slightly different survey forms and survey methodology. These include *katha*, *kua*, boat *katha* and *horgra*. Of these gears, *katha* and *kua* are very important during the drawdown since the flood recession concentrates the fish into small areas of water which make these fishing methods efficient.

5.1.2.1 *Katha*

A *katha* is a collection of brushwood placed in a canal or secondary river which acts as a fish attraction device (FAD). After the brushwood has been put in place the *katha* is left for a period of time and then harvested. The device is repeatedly harvested, once or twice a month during the drawdown period. Although the *katha* is usually static it can be added or removed by fishermen as water levels change for a variety of reasons. Thus a count of *katha* is made on each survey date. The area of each *katha* can be estimated by the amount of brushwood visible at the surface, the bamboo perimeter, and if there is any doubt about the area, it is checked with local fishermen.

Since *katha* is a FAD it was decided that measurement of effort should be the total time in the water. This means that gears are considered to be active on a continuous basis. In the 1992/93 season when recording of catch was done on CAO1 field biologist were estimating time of fishing based on either time since *katha* was constructed, or time since last harvested as appropriate. Other problems were also inherent in using CAO1. The implementation of form CAO1A allows not only the base gear to be recorded (*katha*) but also the number being harvested together and the types of gears being used to harvest them. It also allows a measure of man hours of effort against fishing effort which is required for the economic analysis.

Survey form FEO1 only measures active gears, i.e. those where fishing activity is observed. Since FADs are active even when not attended the total count is required and, in order to deal with this problem for FEO3 which records both active and inactive gears, it is used to provide estimates of effort.

Another difficulty in measuring catch rate is that total harvest may be caught over several days. The option to record catch daily was introduced by provision for total/partial catch and in 1993/94 special teams were assigned to *katha* to monitor whole catch over a period of days after recognising the importance of this type of fishing. In 1992/93 for many sites no catch rates were recorded because of the problems described. Attempts were made to fill such gaps with secondary data on fishing frequencies and catch values collected from *katha* and *kua* owners.

Processing Steps

A catch rate per month is derived for site/location/month/*katha*. This is multiplied by the number of times *katha* is fished in the month. The total is multiplied by the count of gears on site for that month to give total catch.

Designation of site/location is determined by reference to the MON_SCH file.

Records from both CAO1 and CAO1A are used in conjunction with CAO2 and CAO3 to calculate catch rate. The total weight of fish caught by site/location/month/gear is summed from the individual records on CAO2, and from CAO3 after the subsampled data has been raised to full catch in the normal way.

A catch rate per gear is derived by dividing total weight by the sum of numbers of gears used to catch these fish. These values are obtained from the field GRS_OC in both CAO1 and CAO1A. Where the field is blank a value of 1 is assumed. A problem occurs in dealing with record of partial catch. Since the serial number of the first CAO1A is recorded as KA_SL for any partial catch but is left bank for total catch, the number of gears is derived as the number of CAO1 + the number of CAO1A for total catch + the number of unique serial numbers of CAO1A partial catch.

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A catch rate per unit area is derived by dividing total weight by the sum of the areas of the individual gears used. Area on CAO1A is calculated by LENxWID_KA. These figures should always be in metres. Area on CAO1 is calculated using the measured figures if available, otherwise use estimated. If a unit is entered use it. If measured and no unit is entered assume metres. If estimated and no unit is shown assume *hath* (2 *hath* = 1 metre).

Duration of fishing is deemed to be the whole month since gears are fairly static and always in the water. Frequency of fishing is calculated by summing FRQ_EMT on CAO1A, assuming Frequency = 1 for CAO1, and dividing by the number of gears.

Survey data from FEO3 is used to estimate total gears in operation on the site. Both active and inactive gears are deemed to be fishing. For each survey date sum all the active and inactive gear counts for surveys on that day. Where there are 3 or more surveys omit the highest and lowest counts and calculate the mean from the remaining surveys. If less than 3 assume the number of gears is 0 and flag for examination. For the North West Region 1 or 2 surveys are also acceptable but under these circumstances the highest and lowest are not removed (this is basically because the teams in the NW filled the forms in a different way).

The product of gear count and frequency of fishing gives monthly effort.

Monthly effort x Catch rate gives the estimate of total monthly catch. During the flood recession and dry period of 1993/94 individual areas of many *katha* in each site were recorded and formed a useful frame on which to base area calculations.

5.1.2.2 Boat *katha* and *horgra*

A boat *katha* is a boat which is filled with brushwood and repeatedly sunk for periods of 2 to 14 days in different sites, which effectively creates a FAD. A *horgra* is a large wicker basket which is filled with brushwood and used in the same way as the boat *katha*. Fishing effort is based on immersion time which is calculated by recording date last harvested and subtracting from date of sample interview.

Processing Steps
A catch rate per day is derived for site/location/month/gear using the CAS survey data. A mean daily count of gears is established using FEO3 data. This figure is multiplied by the

number of days in the month to give Effort and the product multiplied by the catch rate to give monthly catch.

Designation of site/location is determined by reference to the MON_SCH file.

For each gear sampled and recorded on either CAO1 or CAO1A the weight of fish is summed using CAO2 or CAO3 normal procedures.

For CAO1 the hours taken to catch fish is converted to the nearest number of whole days by rounding. For CAO1A calculate the number of days taken to catch fish as the difference between observation date (SDATE) and date last emptied of fish (EMT_DATE). If this is less than one day then use the date constructed field instead (CON_DATE).

For each sample the number of days is multiplied by the number of gears (GRS_OC) used to catch fish. The number of gear days is totalled by site/location/month/gear and divided into the total weight of fish to give a catch rate of kg per day per gear by site/location/ month.

Survey data from FEO3 is used to estimate total gears in operation on the site. Both active and inactive gears are deemed to be fishing. For each survey date sum all the active and inactive gear counts for surveys on that day. Where there are 3 or more surveys omit the highest and lowest counts and calculate the mean from the remaining surveys. If it is less than 3, assume the number of gears is 0 and flag for examination. For the North West Region 1 or 2 surveys are also acceptable but under these circumstances the highest and lowest are not removed (this is because the teams in the NW filled the forms in a different way).

The mean count is multiplied by the number of days in the month to give monthly effort. Monthly effort is multiplied by the catch rate to give total catch per month.

5.1.2.3 *Kua*

A *kua* is shallow pit dug in the floodplain. As the water recedes during drawdown, those fish which do not attempt to migrate in to the drainage canals and rivers will remain in the *kua*. *Kua* are typically harvested 2 or 3 times in the dry season and often cleared of fish by final dewatering. Some *kua* contain brushwood and are used as FADs in the same way as *katha*.

The same problems of continuous harvesting over 2 or 3 days apply as for *katha* and data for 1993/93. *Kua* was also limited by field staffing considerations. A new form CAO1B was introduced for *kua* to deal with some of these problems. For *kua* neither FEO1 nor FEO3 is used. Instead tabulated data (i.e. data collected freehand in the field) is used to provide the number of *kua* fished in a particular month up to November 1993. A new supplementary survey was included to provide additional information relating to both *katha* and *kua*.

Processing Steps

A catch rate per month is derived for site/location/month/*kua*. A count of *kua* fished on each site (effort) is multiplied by the catch rate to give total catch for the month.

Designation of site/location is determined by reference to the MON_SCH file.

Records from both CAO1 and CAO1B are used in conjunction with CAO2 and CAO3 to calculate catch rate. The total weight of fish caught by site/location/month/gear is summed from the individual records on CAO2, and from CAO3 after the subsampled data has been raised to full catch in the normal way.

A catch rate per gear is derived by dividing total weight by the sum of numbers of gears used to catch these fish. These values are obtained from the field GRS_OC in both CAO1 and CAO1A. Where the field is blank a value of 1 is assumed. A problem occurs in dealing with record of partial catch. Since the serial number of the first CAO1A is recorded as KU_SL for any partial catch but is left bank for total catch, the number of gears is derived as the number of CAO1 + the number of CAO1A for total catch + the number of unique serial numbers for CAO1A partial catch.

A catch rate per unit area is derived by dividing total weight by the sum of the areas of the individual gears used. The area on CAO1A is calculated by LEN_KU x WID_KU. These figures should always be in metres. The area on CAO1 is calculated using the measured figures if available, otherwise use estimated. If a unit is entered use it. If measured and no unit is entered assume metres. If estimated and no unit is shown assume *hath* (2 *hath* = 1 metre).

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A count of *kua* fished on each site is made and recorded on file KUA_FACT. SAMPLED is a count of *kua* sampled, M_TOTAL is the number fished in the month and S_TOTAL is the total for the site. (If a *kua* is fished more than once this is reflected in M_TOTAL).

M_TOTAL x Catch rate gives the estimate of total monthly catch. During the flood recession and dry period of 1993/94 individual areas of many *kua* in each site were recorded and these formed a useful frame on which to base area calculations.

5.1.3 Fish movement - hatchling

The procedures, results and implications of hatchling study have been presented in a separate volume, Supporting Volume No. 11 of the Draft Final Report. The data processing steps are briefly described here.

Hatchling Supply Rate

For convenience of comparison and algebraic manipulation, hatchling numbers caught by a net are divided by the period of time (in hours) for the catch. This gives hatchling number per hour, which is called here hatchling supply rate. Daily and monthly average hatchling numbers are obtained from the hatchling supply rates of survey times.

Water Velocity

Water velocity is likely to have some effect on hatchling supply. Water velocity is measured by two methods: (i) float and (ii) current meter.

(i) For the float method, an object is floated downstream. The distance (in metre) covered by the object, divided by the time (in second) taken, is the water velocity (metre per second).

(ii) For the meter method, the number of revolutions per second of the propeller attached to the water meter placed underwater, is obtained at each survey time.

If the number of revolutions per second is less than 0.2 or is between 0.32 and 11.28, then water velocity in metre per second, is given by

$$0.013 + 0.2512\ n$$

or

$$0.0008 + 0.2667\ n$$

where n is the number of revolutions per second.

Hatchling Density
Water discharge (cubic metre/second) through a net for a hatchling catch, is the product of submerged area (square metre) of the net and water velocity (metre per second).

Hatchling density of a catch of the net is the number of hatchlings (per second) passing through the net, divided by water discharge (metre^3/second) through the net.

Density is thus the hatchling number per metre^3. Daily and monthly average densities are obtained from the individual densities of survey times.

5.2 Processing of Socioeconomic Data

5.2.1 Fisheries catch assessment (FCA)

The FCA data was used to look at two principal issues: the value of the catch, and its distribution between different groups.

Value of the Catch
The FCA estimates of species distribution of catch by site, location, month and gear were used to calculate corresponding catch values. This was achieved by multiplying species weights by estimated species prices, collected in the course of the fish marketing survey.

Monthly price data were collected at four primary markets in each region on each species, when available, for the year 1993. Price trends were followed on 17 indicator species that were widespread, relatively common but sufficiently heterogeneous to cover the spectrum of inland fish types. All other major species were linked to an indicator species, on the advice of experienced market respondents (mainly *aratdar*) as to similarities in their seasonal price movements. Some of the minor species were either not familiar to or differentiated by the market respondents; these were assigned to groups on the basis of scientific species groupings. Differences within groups were allowed for by a markup factor, also derived from interview data. Thus the estimated price of *mrigel*, on which continuous price data were not collected, was that of *rui*, its indicator species, multiplied by 0.69, its markup factor.

The value of catch was estimated by multiplying the estimated catch of each species for each gear in each month on each site by its estimated price. This was then reduced by a marketing margin of 40% for the sites in the North East and 30% elsewhere. These reduction factors were derived from information gathered on fish trading households covered in the socioeconomic village monitoring. The greater margin in the North East is consistent with the much longer carrying distances there.

Classification of Fishermen

The CAO1 forms contained questions relating to the respondents' ranking of different income sources for their household. These were used as a starting point for determining which gears were used by different categories of fishermen and, ultimately, how catch was distributed between them.

The categorization of households according to their dependence on fishing involves the division of a spectrum that extends from those where fishing is the only significant source of income to those where catching fish is a minor seasonal activity perhaps only undertaken by small boys and contributes to household subsistence, not income. The categories used by FAP 17, which are broadly based on those used by FAO, are given in Table 4.3.

Income rankings were used to differentiate between households where fishing was the single (HFC1), the principal (HFC2) and a minor (HFC3) source of income, and those where it contributes principally to household consumption (HFC4).

Households at either end of this spectrum are clearly differentiated and can be classified with little difficulty; the boundaries between the intermediate categories were not always clear, however, particularly those between HFC2 and HFC3, in which where a household ranks fishing as a source of annual income can depend on when members are interviewed, a problem also noted by FAP 6.

Because of the stress laid upon the distributional impact of the FAP by many commentators, further analyses were also undertaken of the first ranked source of income where this was not fishing (i.e. for HFC3 and HFC4 households). In particular a distinction was drawn between households reporting farming as their primary source of income and those giving labour, trade or other.

The users of each gear were classified according to the above criteria, using the four household fishing categories, with an additional breakdown of HFC3 and HFC4 between farmers and non-farmers. For the detailed analyses, gear users were classified by habitat type, flood period and flood control status.

5.2.2 Fish marketing and prices

The Lead Researcher interpreted and analyzed the data under the guidance of the study's Natural Resource Economist. The following is brief description of the major analysis.

Estimation of Return to Capital

The fish marketing chain can be divided into two segments for marketing margin analysis. They are: primary markets to secondary markets, and secondary markets to higher secondary markets (urban wholesale markets). The measure of return to capital used for each segment is the net marketing margin (NMM). NMM is the difference between the sale price and the marketing costs. A full cost method was used to compute NMM.

The data set is based on all costs involved in the process of buying and selling (including utility charges, labour costs, icing, packaging, transport, market charges, *aratdar*'s commission, etc.), the prices received and volumes transacted during the course of one trading day.

Determination of Price Trends

Several sets of prices were used in this study to analyze price trends for major fish species. The Directorate of Agricultural Marketing (DAM) collects major species price data for a large number of wholesale centres across the country. In addition, the Bangladesh Bureau of Statistics (BBS) publishes monthly retail price data for the major species for seven important centres. A third data set, available from the Department of Fisheries (DoF), is the producers' price.

Nominal wholesale prices (DAM) were deflated by the Consumer Price Index for Middle Income Families in Dhaka, published by the BBS. Retail prices (BBS) were converted into real prices by deflating them with the Wholesale Price Index (Agriculture) and then deseasonalized.

Market Integration

Market integration for a system of regional markets is determined by the degree of correlation among price changes across the markets over time and space. To test market integration in Bangladesh, this study prepared price correlation matrices for pairs of markets using average seasonal prices. Average seasonal prices of major fish species in secondary markets (district level) and Dhaka wholesale markets were calculated from monthly price data collected from DAM.

In the investigation of fish market integration, the Ravallion model along with modifications proposed by Timmer and Heytens was used. The model and modifications are discussed in detail in Chapter 7 of the Supporting Volume No. 20 of the Draft Final Report.

6 STATISTICAL ANALYSIS

6.1 Comparison of Catch Rates and Total Catches

Introduction

The design of the stratified random survey for fisheries data collection was such that sampling was carried out at comparable sites both inside and outside FCD/I projects, for each identified habitat type within FCD/I project and region. Ideally, groups of sites were chosen so that for example, any differences in catch rates for a particular gear in a particular month at paired site groups inside and outside FCD/I projects would be solely reflect the fact that one group of sites was inside a project and the other was outside.

The aim of the statistical methodology described below is to allow valid comparisons of the densities of fish by habitat type, FCD/I project and region, at inside and outside groups of sites. Any such differences detected were then to be interpreted in terms of the size of the effect the different densities had on annual catch per unit area. Essentially, the densities of fish (as measured by catch rates) observed at outside sites are taken to be representative of the appropriate habitat type and region. Catches per unit area taken at inside sites are evaluated in comparison with those that would be expected had fish densities at inside sites been the same as those at the comparable outside sites. Thus the analysis has two main steps: (i) modelling of catch rates at inside and outside sites, and (ii) calculation of effects on annual catches per unit area resulting from any differences in density detected.

Indices of fish density at each site or group of sites are available directly through observations of catch rates (catch per unit of fishing effort, CPUE) collected during the surveys. If the density of fish at site s in month m is D_{sm}, then the catch rate by gear g at site s in month m is given by

$$CPUE_{g,s,m} = q_{g,s,m} \cdot D_{s,m}$$

where q_{gsm} is known as the catchability coefficient for gear g at site s and month m. Now, it is reasonable to suppose that the catchability coefficient for a gear in a particular month should not vary with site within the same habitat type, provided the sites are typical of that habitat type. However, even if it is reasonable to assume comparability of catchabilities across sites within a habitat type, the same cannot be said when comparing across gears or months.

Dealing first with gear, it is quite clear that the catchability for a passive trap will be completely different from that for a bag net or large seine net. This difference in catchability between gears does not by itself cause a problem. What it requires is for gears to be considered separately, or at least standardised against each other. Comparison between inside and outside sites, however, does demand that the same gear be used at both inside and outside sites.

Less obvious, perhaps, is that for at least some gears catchabilities may vary with time, even for the same gear. This is especially true for those gears used most during the recession of flood waters, when increased water flows in restricted areas can lead to substantially higher catch rates than would be obtained from the same water body in full flood. The differences in catch rates for the same period in different time periods are a reflection of increased catchability rather than increased density of fish. It is the anticipated variations in catchability amongst gears and months (or seasons) that makes interpretation of catch rates so difficult. How much of any difference seen in catch rates is due to real differences in fish density, or to a change in catchability, or some combination in both?

This is a problem that has been long recognised in the analysis of marine fisheries catch and effort data, and methods exist to cope with the problem. In essence, they rely on selecting a gear and a time period as a standard, and then normalising catch rates for different gears and/or different time periods in terms of that standard. Using this model, estimates are then made of the underlying fish densities (measured in units of catch rates by the standard gear) at inside and outside sites, and these are then compared statistically to determine whether there are differences between inside and outside sites. The essential assumption that has to be made, however, is that differences in catch rate for the same gear and time period are due solely to differences in fish density.

As described below, the actual analyses have been conducted by season rather than month. In some cases, the estimated densities outside were found to be at least as high as the densities inside in each season (or vice versa). In this case, the interpretation is quite straightforward. However, more frequently it was found that the estimated densities were higher inside than outside in some seasons, but lower in other seasons. Interpretation of such findings needs rather more care. The solution adopted was to make predictions of the annual total catch per unit area at inside sites that would have been taken, given the observed effort pattern at inside sites, had the true densities at inside sites been the same as those estimated for outside sites. A simple example makes the approach clear.

Suppose the estimated densities at inside and outside sites are as given in the table 6.1.

Table 6.1 Estimated densities (Example 1)

Season	1	2	3	4	5
Inside densities	0.1	0.2	0.1	0.3	0.2
Outside densities	0.1	0.1	0.2	0.2	0.2

The inside densities are higher in seasons 2 and 4, but lower in season 3. Now suppose that the effort per unit area for a particular gear by season was as given in table 6.2, and assume for ease of calculation that the catchability coefficient for this gear is 1.0. Then the estimated catch per unit area by season for that gear is just the product of the effort per unit area and the density by season. Table 6.2 contains the seasonal catches per unit area calculated using both the inside densities and the outside densities from table 6.1.

Table 6.2 Estimated EPUA and CPUA (Example 2)

Season	1	2	3	4	5	Total
Inside effort	10	10	100	10	10	
CPUA (In)	1	2	10	3	2	18
CPUA (Out)	1	1	20	2	2	26

The effort pattern assumed here is such that by far the most effort is expended in season 3. It then follows that in terms of its effect on annual catch per unit area, it is the higher density outside in season 3 that has by far the greatest effect, and it far outweighs the higher densities inside in seasons 2 and 4. On the basis of this example calculation, it would be concluded that the annual catch per unit area at the inside sites would have been 44% higher if the seasonal fish densities had been the same on the inside as they were on the outside.

Data Sources

Procedures used to collect and store the basic catch rate and fishing effort data have been described in considerable detail in the Interim Report and in Section 4 and 5 of this report, so only features directly relevant to the statistical analysis described in this section will be reiterated here.

The data on catch rates by gear were collected during the catch rate survey. These data consisted of individual observations of catch by a gear and the fishing effort expended by that gear to take the recorded catch. Observations were made throughout the sampling day. Normally there were two sampling days per month at each site.

Sites representing similar habitat types by FCD/I project and region were identified for each of the comparisons attempted. Catch rate observations for these groups of sites were treated as independent replicate observations during the statistical analysis. It was also decided to carry out the analysis by season for the 12 months from March 1993 to February 1994. This was done in order to avoid some of the problems of missing observations or very small numbers of observations for some gears and months. Seasons used are given in table 6.3.

Table 6.3 List of seasons

Season	1	2	3	4	5
Months	March - April	May - June	July - September	October-November	December-February

Data for each sampling day in a season were also treated as replicate observations in the analysis.

Estimates of seasonally pooled catch rates for a gear were calculated as effort weighted averages of the individual catch rate observations. Thus, for a gear and season, if the catch rate observations consist of n pairs of observations of catch for that gear C_i and the corresponding effort f_i, then the seasonally pooled catch rate is

$$CPUE = \frac{\sum_{i=1}^{n} f_i \frac{C_i}{f_i}}{\sum_{i=1}^{n} f_i} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} f_i}$$

Independently of the catch rate data collected during the catch rate survey, data on the total fishing effort by gear at each site was collected during the fishing effort survey. If the estimated total effort per unit area for a gear at a group of sites and a season is E, then the estimated catch per unit area for that gear, site group and season is

$$CPUA = CPUE \,.\, E$$

It should be noted that by pooling over seasons in this way, slightly different estimates of catch per unit area will be derived than those tabulated elsewhere in this report, which have been pooled by month, rather than season. Another source of difference is that in attempting to get the best possible estimates of total catch elsewhere in the report, estimated catch rates have been used in cases where there are missing data for a gear and month in the catch rate survey. While this is entirely appropriate when trying to estimate total catches, in the statistical analysis it is appropriate to treat these data simply as missing observations.

The number of gear types potentially available for analysis is very large, and reliable measures of fishing effort are not available for all of them. The two clearest examples are *katha*, which are essentially fish aggregation devices, and *kua*. While total catches have been calculated elsewhere in this report for these gears, no measure of fishing effort comparable with the other more standard fishing gears has been identified. Thus data for these gears has been omitted from the statistical analysis of catch rates.

In addition, in order to reduce the analyses to a reasonable size, for each statistical comparison attempted catch rate data were extracted for only the dominant gears. Generally, these were defined as those gears, excluding *katha* and *kua*, that took at least 90% of the annual catch per unit area for the nominated group of sites. Normally, this selection process was sufficient to reduce the total number of gears analysed in each comparison to a maximum of 10. Where the number exceeded 10, the cutoff percentage was reduced to achieve a maximum of 10 gears.

Statistical Model

The statistical model used and the method of analysis adopted for comparisons of catch rates is a variant of the log-linear or generalized linear models used routinely in the analysis of marine fishery catch rate data (see, for example, Allen and Punsley 1984[1]).

Let

$$CPUE_{i,s,g,n} = \frac{C_{i,s,g,n}}{f_{i,s,g,n}}$$

be the nth catch rate at outside (i=1) or inside (i=2) sites in season s (s=1,.., 5) by gear g (g=1,..,10). Then the model used is

$$E(CPUE_{i,\,s,\,g,\,n}) = \exp(S_s + G_g + S.G_{s,\,g} + S.I_{s,\,i})$$

where S_s is a season factor, representing the underlying fish density in season s, G_g is a gear factor representing the overall relative catchability of gear g, $S.G_{sg}$ is a season-gear interaction term allowing the different relative catchabilities for gears in each season, and $S.I_{si}$ is an interaction term allowing for possibly different underlying fish densities by season at inside and outside sites. Equality of fish densities by season at inside and outside sites is examined directly by testing whether the season-in-out interaction term is significantly different from zero. All factors are scaled relative to the gear effect for gear 1.

Examination of the replicate catch rate observations revealed that the frequency distribution of these observations was extremely skewed. The analysis was therefore carried out under the assumption that these observations were gamma distributed. Very occasionally, the recorded catch rate was exactly zero. In these cases, the catch rate was set at 0.0001. For consistency with the methods used to calculate observed seasonally pooled catch rates, each catch rate observation was assigned a weight proportional to the recorded effort for that observation. To take account of the rather different units in which effort by different gears was measured, weights for each gear were calculated as proportions of the overall average effort for that gear.

This model fits neatly into the category of generalized linear models for which the GLIM 4 statistical computer package was specifically designed (Francis, Green and Payne, 1993[2]). In the terminology of that package, the generalized linear model has a log link with gamma error. The GLIM 4 package allows estimation of the parameters of the model and their variance-covariance matrix by maximum likelihood and tests of hypotheses via an analysis of deviance. Estimates of the predicted catch rates at both inside and outside sites and their standard errors are also directly available from the GLIM 4 output. These are then used with separate estimates of the seasonal fishing effort by gear to obtain estimates of the seasonal and total annual catch per unit area.

Illustrative Analysis

To illustrate the statistical methodology, an illustrative example is briefly described. The data are drawn from those for an inter-regional comparison between North West and North Central low elevation floodplain/*beel* sites inside and outside the Pabna Irrigation Development.

The first step is to identify the principal gears for analysis. Table 6.4 lists in descending order the catches per unit area by gear at inside and outside sites over the period March 1993 to February 1994.

Table 6.4 Catch per unit area (CPUA) for principal gears

Gear name (Bengali)	Inside sites		Outside sites	
	%	Cum %	%	Cum %
Ber jal	19.9	66.4	5.4	77.7
Current jal (Stationary)	7.7	88.9	9.9	63.1
Dhor jal	-	-	2.5	91.5
Doiar trap	24.6	24.6	-	-
Jhaki jal	2.7	91.6	9.2	72.4
Thella jal	21.9	46.5	31.9	31.9
Ucha	-	-	9.9	53.3
Veshal	-	-	11.4	43.3
Daun	14.8	81.2	2.7	89
Tukri	-	-	3.3	87
Hand fishing	-	-	5.2	82.9

Catches by gears were listed initially until they accounted cumulatively for at least 90% of the total catch by all gears at the sites selected. Six gears accounted for at least 90% of the catch per unit area at inside sites and 10 gears at inside sites. Five gears were used at both inside and outside sites and the overall number of distinct gears was 11. This is one more than was decided to be the maximum to include in an analysis, so the cut-off percentage was dropped to 88.9%. Now there are only 4 gears in common [*thella jal*, *current jal* (Stationary), *ber jal* and *daun*] and 10 distinct gears overall. Selecting from the catch rate database the observations for the appropriate sites by the 10 selected gears resulted in a total of 1111 individual observations for analysis. An additional 5 dummy observations were added to ensure the GLIM package calculated variances of predicted catch rates for all gears.

The output from the GLIM 4 analysis is shown in Appendix 1. Before examining this in detail, it is first necessary to see how well the model fitted the data. This is best seen by looking at plots of observed seasonally pooled catch rates at inside and outside sites and the values predicted for these by the model. The plots for the four gears used in common are shown in Fig. 6.1. With one exception, the agreement between observed and predicted catch rates is very good, especially when the intrinsic variability in the data is borne in mind. That one exception is the observed catch rate for *current jal* (stationary) in season 1, where the catch rate is very much higher than predicted under the model. Note also that for both *ber jal* and *daun*, there are missing catch rate observations at outside sites.

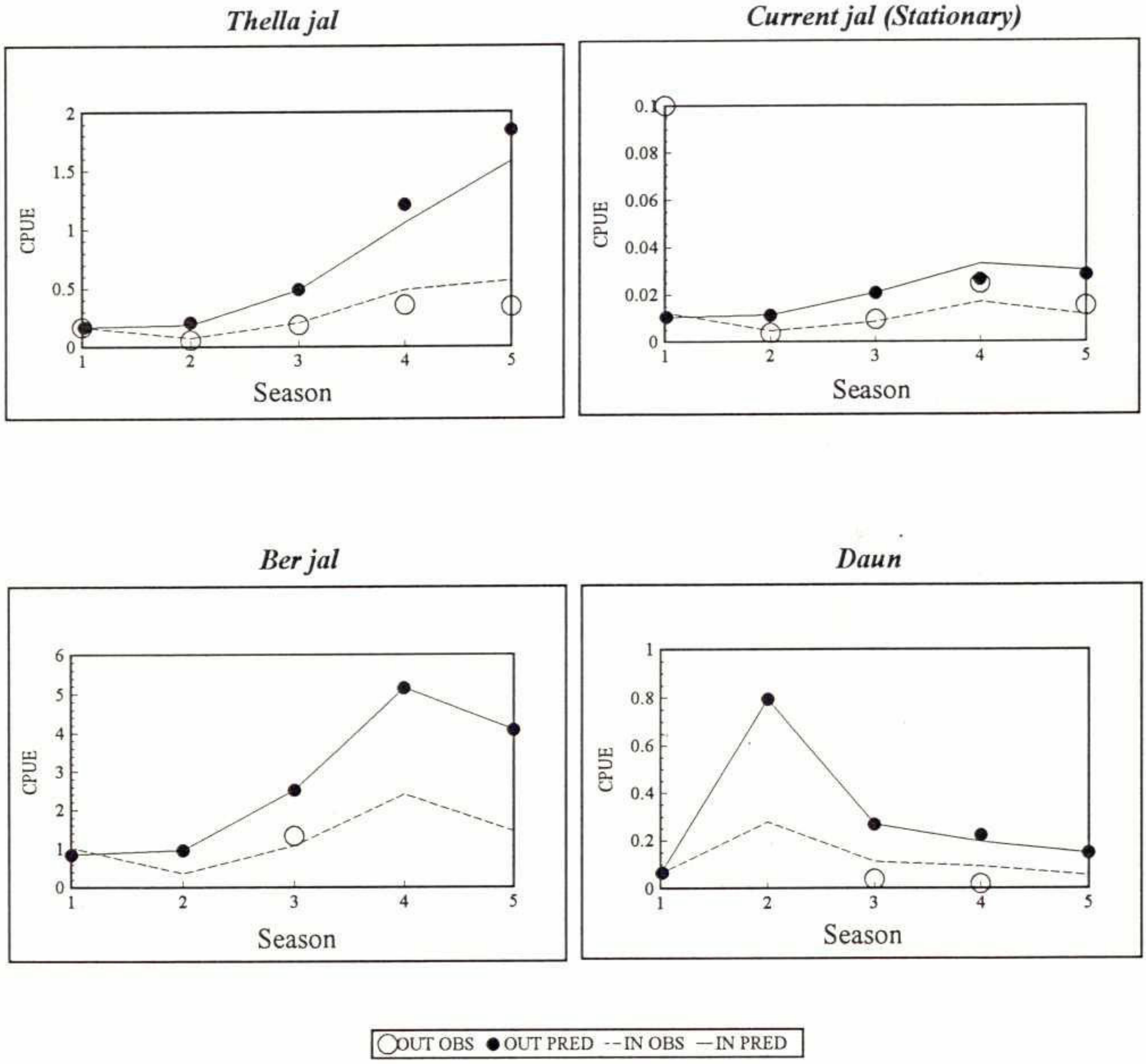
Returning to the catch rate data base, it was found that the observed pooled catch rate for *current jal* (stationary) in season 1 at outside sites was calculated from just a single observation. For some seasons and gears, it is not uncommon for the seasonally pooled catch rate to have been calculated from the order of 100 observations. It is not at all unlikely that this single observation is unreliable. This was examined by removing that observation and repeating the GLIM 4 analysis. The results (not shown) in terms of parameter estimates and significance levels were almost identical. The lack of fit of the model for that gear and season outside did not affect the analysis at all.

Turning attention now to the results themselves, having satisfied ourselves that the model is providing a reasonable fit to the data, we first see that the results of the statistical test to determine whether the season-inside-outside (SEAS.INOUT) interaction is significant. It is, and very highly significant [see line marked (1) in GLIM 4 output]. This implies that there are statistically significant differences in seasonal fish densities at inside and outside sites. To determine the extent and direction of these, it is necessary to review the individual parameter estimates for the SEAS.INOUT terms. These are on the line marked (2) and following lines on the GLIM 4 output.

The first of these terms is negative, suggesting that the density is slightly lower at inside than outside sites in season 1. However, the estimate is considerably less than its estimated standard error, so this difference would not be statistically significant. In all other cases, the individual estimates of INOUT differences by season are positive, and each is statistically significantly different from zero, when judged in terms of its estimated standard error. The conclusion is that, with the exception of season 1, where there is no significant difference in densities inside and outside, in all other seasons the densities of fish at inside sites are statistically significantly higher than at outside sites for this habitat type. This direction of the difference is also apparent from Figure 6.1.

The last step in the analysis is to interpret these differences in terms of expected differences in annual catch per unit area they imply. From the main database, the effort per unit area by gear was extracted for the sites analysed, as shown in Appendix 2. Multiplying the effort per unit area for each gear by its observed and predicted catch rates leads to the table of catches per unit area as shown in Appendix 3.

Figure 6.1 Comparison of observed and predicted CPUEs by season for low elevation floodplain/*beel* sites outside and inside the Pabna Irrigation and Development Project



Note: Sites inside are from North West Region
Sites outside are from North Central Region

The effort table contains two columns for each season. The first of the two, labelled 'Obs' records the total effort per unit effort for that season for each gear, in the usual units for that gear. The second column, labelled 'STD,' is the estimated effort per unit area standardised in terms of effort by the standardising gear, which is the first gear on the list, *thella jal*. The standardising constants are those extracted from the GLIM 4 output, such that, for example, the standardised effort for *current jal* (stationary) in season 3 is given by the database effort for that gear and season, multiplied by the exponential of the sum of the gear(2) effect and the gear(2) x seas(3) interaction term. Standardising in this way allows all effort to be expressed in similar units and thus a total standardised effort by all gears to be calculated for inside and outside sites. For the comparison analysed, the total standardised effort at inside sites is 153.6 push net hours, while at outside sites it is 82.4 push net hours. On this basis, one would expect that the catch per unit area at inside sites should be nearly double that for outside sites, just because of the higher fishing effort expended at inside sites.

In fact, the observed total annual catch per unit area at inside sites is much more than double that at outside sites. This is due to the higher densities of fish at the inside sites. The final table of catches per unit area by season and gear makes this clear. The last two columns for each season for the inside sites list the catches per unit area predicted by multiplying the inside catch rates (predicted using the statistical model) by the inside effort per unit area. The corresponding estimates are calculated by multiplying by the outside predicted catch rates. These latter values are much lower than the former, quantifying the effects on total annual yield caused by the higher densities.

6.2 Regression and Correlation Analysis

Let (x_1,y_1) (x_2,y_2) .... (x_n,y_n) be n pairs of values of 2 variables, y and x, of which y is dependent and x independent. Regression line of variable, y, on variable x is given by

$$y = a + bx$$

where a is called intercept and b the regression coefficient or slope. The expressions for a and b are obtained by minimising sum of squares due to error (SSE) and the procedure is known as least squares method.

The computing formulae are

$$b = \frac{\Sigma(x_i-\bar{x})(y_i-\bar{y})}{\Sigma(x_i-\bar{x})^2}$$

and $a = \bar{y}-b\bar{x}$

where $\bar{y} = \Sigma y_i / n$ and $\bar{x} = \Sigma x_i / n$ are the means of n values of y and n values of x respectively.

The correlation coefficient between 2 variables, x and y, is given by

$$r = \frac{\Sigma(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\Sigma(x_i-\bar{x})^2\Sigma(y_i-\bar{y})^2}}$$

Once the regression line is computed from a given set of values of x and y, the significance of the regression line can be tested by parametric t-test assuming variable y to be normally distributed. The t-test can be used for either regression coefficient, b or correlation coefficient, r.

(a) Test of hypothesis: b = 0 i.e., regression line is not significant

Here, test-statistic is

$$t = \frac{b}{\sqrt{\Sigma(x_i-\bar{x})^2 MSE}}$$

with (n-2) degrees of freedom (df) and MSE as SSE/(n-2) for the fitted model.

(b) Test for hypothesis: r = 0

Here, test-statistic is

$$t = \frac{r\sqrt{(n-2)}}{\sqrt{1-r^2}}$$

with $(n-2)$ *df*

If the calculated value of t is greater than or equal to the 5% or 1% value of t having same (n-2) df from t-table, then the hypothesis is rejected at 5% or 1% level of significance. Otherwise, the hypothesis is accepted. Alternatively, the significance level (P-value) can be obtained.

The two tests give the same result about the regression line.

6.3 Spearman's Rank Correlation

When the values of y and/or x are not normally distributed, the values of y and those of x are ranked separately. The correlation is then computed between the two sets of ranks.

Spearman's rank correlation is given by

$$\rho = \frac{1-6\Sigma d_i^2}{n(n^2-1)}$$

where d_i is the difference between ranks of x and y for ith pair of values of x and y, i = 1, 2, ..., n. The same t-test at (b) above is used to test significance of ρ assuming ranks to be approximately normally distributed.

6.4 Non-parametric Tests

Non-parametric tests are used to compare distributions and the locations (central values) when the data of the variables are not normally distributed. The powers of the non-parametric tests are usually less than those of the corresponding parametric tests except for large samples.

Comparison between 2 Independent Samples

The Mann-Whitney U-test is used to compare distributions and locations of 2 independent samples. In this case, values of 2 samples, A and B, are ranked together. Then compute U_i as the number B values that precede ith A observation or vice versa, i = 1, 2, ..., n. The sum of these counts is U-statistic. For test of significance, computed values of U can be compared with the values of Table of U distribution prepared for the purpose. For sample sizes > 10, the normal test is used by standardizing U-values i.e,

$$z = \frac{U-\bar{U}}{\sqrt{Var(U)}}$$

is a standardised normal variable.

Calculated values of z are compared with 5% or 1% values of the normal table. Significance level (P-value) may also be obtained. This test is equivalent to the unpaired parametric t-test.

Comparison between 2 Dependent Samples

For dependent samples, paired values of 2 samples are considered. Let $D_i = x_i - y_i$ be the difference between 2 values of x and y of the same ith pair, i = 1, 2, .., n. The absolute values of D_i excluding 0, are ranked. Then calculate rank sums (T) for positive and negative values of D_i separately. The minimum of 2 rank sums, is then compared with 5% and 1% values of T-table prepared for the purpose. For large n, the z-test (normal test) is used in the same way as in (a).

Comparison between 3 or more Independent Samples

The Kruskal-Wallis one-way analysis of variance (ANOVA) is used to compare k ≥ 3 populations and their locations. In this case, all sample observations are ranked together from the smallest to the largest. Let R_i denote the sum of such ranks of all observations in ith sample of size n_i, i = 1, 2, ..., k.

To test equality of distributions and locations, The Kruskal-Wallis statistic is

$$H = 12\{\Sigma R_i^2 \ / \ n_i - 3(n+1)\} \ / \ n(n+1)$$

with $n = \Sigma n_i$.

The statistic H is approximately distributed as χ^2 with (k-1) degrees of freedom (df). Computed values of H are compared with the values obtained from χ^2-table for same df. This test is equivalent to the parametric one-way ANOVA test.

6.5 Comparisons of Hatchling Supply Rates or Densities by Non-parametric Tests

Non-parametric tests are used to compare distributions and the locations (central values) because the data of the above rates (variables) are not usually normally distributed. The powers of the non-parametric tests are usually less than those of the corresponding parametric tests except for large samples.

Comparison between 2 Independent Samples (Unpaired Comparison)

The Non-parametric Mann-Whitney U-test is used to compare distributions and locations of 2 independent samples. In this case, values of 2 samples, A and B, are ranked together. Then compute U_i as the number B values that precede ith A observation or vice versa, i = 1, 2, ..., n. The sum of these counts is the U-statistic. For test of significance, computed values of U can be compared with tabulated values of U distribution prepared for the purpose. For sample sizes > 10, the normal test is used by standardizing U-values i.e,

$$z = \frac{U-\bar{U}}{\sqrt{Var(U)}}$$

is a standardised normal variable. The values of $\bar{U}$ and var (U) are obtained from the distribution of U.

Calculated values of z are compared with 5% or 1% values of normal table. The significance level (P-value) may also be obtained. This test is equivalent to the unpaired parametric t-test for normal samples.

The sample values may be hatchling supply rates or densities on different dates for inside and outside of an FCD/I project.

Comparison between 2 Dependent Samples (Paired Comparison)

For dependent samples, paired values of 2 samples are considered. The Non-parametric Wilcoxon sign test is used in this case. Let $D_i = x_i - y_i$ be the difference between 2 values of x and y of the same ith pair, i = 1, 2, .., n. The absolute values of D_i excluding 0, are ranked. Then calculate rank sums (T) for positive and negative values of D_i separately. The minimum of 2 rank sums is then compared with 5% and 1% values of the T-table prepared for the purpose. For large n, the z-test (normal test) is used in the same way as in (a).

The test is equivalent to the parametric paired the t-test for normal samples.

Comparison between 3 or more Independent Samples

The Non-parametric Kruskal-Wallis one-way analysis of variance (ANOVA) is used to compare k ≥ 3 populations and their locations. In this case, all sample observations are ranked for all samples together from the smallest to the largest. Let R_i denote the sum of such ranks of all observations in ith sample of size n_i, i = 1, 2, ..., k.

To test equality of distributions and locations, the Kruskal-Wallis statistic is

$$H = 12\{\Sigma R_i^2 \ / \ n_i - 3(n+1)\} \ / \ n(n+1)$$

with $n = \Sigma n_i$.

The statistic H is approximately distributed as χ^2 with (k-1) degrees of freedom (df). Computed values of H are compared with the values obtained from χ^2-table for the same df.

This test is equivalent to the parametric one-way ANOVA test.

Correlation analysis is sometimes used to find the relationship between 2 sets of data.

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Appendix 1 Sample GLIM 4 output

GLIM 4, update 8 for IBM etc. 80386 PC / DOS on 12-May-1994 at 07:44:45
(copyright) 1992 Royal Statistical Society, London

```
$C nw v nc pabna floodplain/beel low
$units 1116$
$data INOUT SEAS MONTH SMON GEAR CPUE EFAVG$
$factor INOUT 2 SEAS 5 GEAR 10$
$dinput 7$
$err g$
$link l$
$yvar CPUE$
$weight EFAVG$
$cycle 50 1$
$num SS1 df1 s2 $
$num SS2 df2 F21 df21 pF $
$C
$fit SEAS + GEAR +SEAS.GEAR +SEAS.INOUT$
  deviance =  972.28 at cycle 1
  deviance =  797.54 at cycle 2
  deviance =  786.15 at cycle 3
  deviance =  786.06 at cycle 4
  deviance =  786.06 at cycle 5
residual df = 1068

$cal SS1=%dv : df1=%df : s2=%sc$
$RECYCLE 50 1$
```

NOW TEST WHETHER THE SEAS.INOUT INTERACTION IS SIGNIFICANT

```
$C
$FIT - SEAS.INOUT $
  deviance =   857.35 at cycle 1
  deviance =   852.66 at cycle 2
  deviance =   852.63 (change =   +66.57) at cycle 3
residual df =  1073    (change =    +5   )

$cal SS2=%dv : df2=%df$
$cal df21=df2-df1 : F21=((SS2-SS1)/df21)/s2 :
  pF=(1-%fp(F21,df21,df1))$
$print : 'F ='F21' with 'df21' and 'df1' degrees of freedom (p='pF')'$

F =   18.09 with    5.000 and    1068. degrees of freedom (p=  0.    )    ----------- (1)
$C
$C

$RECYCLE 50 1$
$FIT +SEAS.INOUT$
  deviance =   793.16 at cycle 1
  deviance =   786.51 at cycle 2
  deviance =   786.10 at cycle 3
  deviance =   786.06 (change =   -66.57) at cycle 4
residual df =  1068    (change =    -5   )

$fit -1$
  deviance =   786.06 at cycle 1
  deviance =   786.06 (change =  -0.003588) at cycle 2
residual df =  1068    (change =  0       )
```

```
$C
$C NOW THE FINAL PARAMETER ESTIMATES
$C
$dis E$
     estimate     s.e.       parameter
   1 -1.808       0.2549     SEAS(1)
   2 -2.825       0.4268     SEAS(2)
   3 -1.634       0.1884     SEAS(3)
   4 -0.7004      0.1386     SEAS(4)
   5 -0.6316      0.1962     SEAS(5)
   6 -2.581       0.2663     GEAR(2)
   7 1.833        0.4667     GEAR(3)
   8 -0.8520      0.6116     GEAR(4)
   9 -0.1741      0.6477     GEAR(5)
  10 0.03543      0.5055     GEAR(6)
  11 -0.8813      0.3603     GEAR(7)
  12 -1.293       1.597      GEAR(8)
  13 -1.894       0.7111     GEAR(9)
  14 -3.466       0.2813     GEAR(10)
  15 -0.1180      0.5295     SEAS(2).GEAR(2)
  16 -0.1135      0.7590     SEAS(2).GEAR(3)
  17 2.441        1.379      SEAS(2).GEAR(4)
  18 -0.5685      0.9195     SEAS(2).GEAR(5)
  19 0.000        aliased    SEAS(2).GEAR(6)
  20 1.307        0.6469     SEAS(2).GEAR(7)
  21 0.000        aliased    SEAS(2).GEAR(8)
  22 0.000        aliased    SEAS(2).GEAR(9)
  23 0.03775      0.5547     SEAS(2).GEAR(10)
  24 -0.5644      0.3095     SEAS(3).GEAR(2)
  25 -0.1309      0.5009     SEAS(3).GEAR(3)
  26 0.2537       0.6367     SEAS(3).GEAR(4)
  27 0.2720       0.7734     SEAS(3).GEAR(5)
  28 0.3791       0.6016     SEAS(3).GEAR(6)
  29 0.000        aliased    SEAS(3).GEAR(7)
  30 0.000        aliased    SEAS(3).GEAR(8)
  31 1.417        0.9336     SEAS(3).GEAR(9)
```

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32	-0.8978	0.3396	SEAS(3).GEAR(10)
33	-0.8507	0.2990	SEAS(4).GEAR(2)
34	-0.2342	0.5106	SEAS(4).GEAR(3)
35	-0.8203	0.6295	SEAS(4).GEAR(4)
36	0.000	aliased	SEAS(4).GEAR(5)
37	-0.7931	0.5433	SEAS(4).GEAR(6)
38	0.3661	0.4788	SEAS(4).GEAR(7)
39	-0.06846	1.659	SEAS(4).GEAR(8)
40	0.5351	0.8669	SEAS(4).GEAR(9)
41	-1.333	0.3625	SEAS(4).GEAR(10)
42	-1.320	0.3244	SEAS(5).GEAR(2)
43	-0.8580	0.5368	SEAS(5).GEAR(3)
44	-1.440	0.6520	SEAS(5).GEAR(4)
45	0.000	aliased	SEAS(5).GEAR(5)
46	-1.103	0.5894	SEAS(5).GEAR(6)
47	0.3665	0.4718	SEAS(5).GEAR(7)
48	-0.4208	1.642	SEAS(5).GEAR(8)
49	-0.02533	0.9699	SEAS(5).GEAR(9)
50	-2.029	0.3416	SEAS(5).GEAR(10)
51	-0.1724	0.3372	SEAS(1).INOUT(2) ---------------------- **(2)**
52	1.023	0.4268	SEAS(2).INOUT(2)
53	0.8811	0.1334	SEAS(3).INOUT(2)
54	0.7225	0.1244	SEAS(4).INOUT(2)
55	1.049	0.2049	SEAS(5).INOUT(2)

scale parameter 0.7360

$tab the cpue mean with efavg for inout;gear;seas$

-- the table contains empty cell(s)

INOUT	GEAR	SEAS 1	2	3	4	5
1	1	0.15187897	0.05400156	0.17250000	0.34042805	0.32488599
	2	0.10000000	0.00431299	0.00876407	0.02381836	0.01504106
	3	0.00000000	0.00000000	1.38485765	0.00000000	0.00000000
	4	0.00000000	0.00000000	0.04519724	0.02314916	0.00000000
	5	0.00000000	0.02822000	0.21512784	0.41707423	0.00000000
	6	0.16988282	0.00000000	0.29526928	0.23269913	0.18276939
	7	0.06792622	0.09077697	0.00000000	0.29655290	0.31778979
	8	0.04500000	0.00000000	0.00000000	0.12722155	0.09580059
	9	0.02467000	0.00000000	0.12100250	0.12754253	0.07800000
	10	0.00001000	0.00001000	0.00001000	0.00001000	0.00001000
2	1	0.14578724	0.18385792	0.47158927	1.16127527	1.81809735
	2	0.01019054	0.01099936	0.01987162	0.02581077	0.02713461
	3	0.86258185	0.91999835	2.47801924	5.05594778	4.02143145
	4	0.05886809	0.80769002	0.27721468	0.22660896	0.15332364
	5	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	6	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	7	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	8	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	9	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
	10	0.00431064	0.00534827	0.00599248	0.00841645	0.00622875

$tab the %fv mean for inout;gear;seas$

-- the table contains empty cell(s)

INOUT	GEAR	SEAS 1	2	3	4	5
1	1	0.163970	0.059306	0.195067	0.496411	0.531727
	2	0.012408	0.003988	0.008395	0.016044	0.010748
	3	0.000000	0.000000	1.069646	0.000000	0.000000
	4	0.000000	0.000000	0.107232	0.093235	0.000000
	5	0.000000	0.028220	0.215128	0.417074	0.000000
	6	0.169883	0.000000	0.295269	0.232699	0.182769
	7	0.067926	0.090777	0.000000	0.296553	0.317790
	8	0.045000	0.000000	0.000000	0.127222	0.095801
	9	0.024670	0.000000	0.121003	0.127543	0.078000
	10	0.005122	0.001924	0.002483	0.004087	0.002183
2	1	0.138007	0.164884	0.470822	1.022360	1.517431
	2	0.010443	0.011089	0.020261	0.033042	0.030673
	3	0.862582	0.919998	2.581741	5.055948	4.021432
	4	0.058868	0.807690	0.258819	0.192017	0.153324
	5	0.000000	0.000000	0.000000	0.000000	0.000000
	6	0.000000	0.000000	0.000000	0.000000	0.000000
	7	0.000000	0.000000	0.000000	0.000000	0.000000
	8	0.000000	0.000000	0.000000	0.000000	0.000000
	9	0.000000	0.000000	0.000000	0.000000	0.000000
	10	0.004311	0.005348	0.005992	0.008416	0.006229

$ext %vl$

$tab the %vl mean for inout;gear;seas$

-- the table contains empty cell(s)

INOUT	GEAR	SEAS 1	2	3	4	5
1	1	0.064954	0.182170	0.035491	0.019212	0.038510
	2	0.134400	0.172263	0.013813	0.014142	0.038971
	3	0.000000	0.000000	0.028500	0.000000	0.000000
	4	0.000000	0.000000	0.027058	0.020400	0.000000
	5	0.000000	0.243758	0.143137	0.400317	0.000000
	6	0.190542	0.000000	0.070932	0.020458	0.053394
	7	0.064876	0.106476	0.000000	0.080163	0.054274
	8	2.484005	0.000000	0.000000	0.184003	0.109792
	9	0.440699	0.000000	0.330524	0.226645	0.396628
	10	0.143046	0.205697	0.035827	0.054650	0.054659
2	1	0.049782	0.204999	0.018189	0.013093	0.024875
	2	0.021467	0.022959	0.006843	0.008309	0.015817
	3	0.167991	0.153346	0.014974	0.029873	0.045514
	4	0.324321	1.322238	0.013156	0.010920	0.026163
	5	0.000000	0.000000	0.000000	0.000000	0.000000
	6	0.000000	0.000000	0.000000	0.000000	0.000000
	7	0.000000	0.000000	0.000000	0.000000	0.000000
	8	0.000000	0.000000	0.000000	0.000000	0.000000
	9	0.000000	0.000000	0.000000	0.000000	0.000000
	10	0.029336	0.023545	0.018030	0.039181	0.012680

$stop

Appendix 2 Total EPUA by season for low elevation floodplain/beel sites in Pabna Irrigation and Development Project

GEAR	SEASON 1		2		3		4		5		TOTAL	
	Obs	STD	Obs	STD	Obs	STD	Obs	STD	Obs	STD	Obs	STD
Thella jal	1.1	1.1	1.0	1.0	4.6	4.6	12.2	12.2	4.0	12.2	23.0	31.1
Current jal (Stationary)	0.2	–	0.7	–	85.2	3.7	56.4	1.8	11.5	0.2	154.1	5.8
Ber jal	–	–	–	–	0.9	4.9	0.5	2.3	–	–	1.4	7.2
Daun	–	–	–	–	6.4	3.5	35.6	6.7	–	–	42.0	10.2
Veshal	–	–	0.6	0.3	3.2	3.5	4.5	3.8	–	–	8.2	7.5
Ucha	0.2	0.2	–	–	2.6	3.9	7.4	3.4	2.7	0.9	12.9	8.5
Jhaki jal	2.2	0.9	1.2	1.9	0.1	–	5.2	3.1	1.6	1.0	10.2	6.9
Hand fishing	0.6	0.2	–	–	–	–	7.1	1.8	2.2	0.4	9.9	2.4
Tukri	0.1	–	–	–	3.4	2.1	2.3	0.6	0.5	0.1	6.4	2.8
Doiar trap	–	–	–	–	–	–	–	–	–	–	–	–
TOTAL		2.4		3.2		26.2		35.7		14.8		82.4
Thella jal	1.3	1.3	0.1	0.1	7.2	7.2	9.8	9.8	9.8	9.8	28.1	28.1
Current jal (Stationary)	19.5	1.5	30.7	2.1	104.6	4.5	115.9	3.7	115.9	2.3	386.7	14.1
Ber jal	0.3	1.8	0.1	0.3	4.1	22.6	2.8	13.7	2.8	7.4	10.0	45.8
Daun	0.2	0.1	0.7	3.2	20.6	11.3	29.9	5.6	29.9	3.0	81.3	23.3
Veshal	–	–	–	–	–	–	–	–	–	–	–	–
Ucha	–	–	–	–	–	–	–	–	–	–	–	–
Jhaki jal	–	–	–	–	–	–	–	–	–	–	–	–
Hand fishing	–	–	–	–	–	–	–	–	–	–	–	–
Tukri	–	–	–	–	–	–	–	–	–	–	–	–
Doiar trap	222.8	7.0	575.7	18.7	750.3	9.6	573.2	4.7	573.2	2.4	2695.3	42.3
TOTAL		11.7		24.4		55.2		37.5		24.9		153.6

Notes: 1. The columns labelled "obs" contain the observed fishing effort per unit area pooled across all sites for the nominated gear. The columns labelled STD contain the estimated equivalent standardised effort, measured in the units of effort of the gear in the first row, which here is the Thella jal.

2. – denotes zero

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Appendix 3 Total CPUA by season for low elevation floodplain/beel sites in Pabna Irrigation and Development Project

	Gear name	Season															Total		
		1			2			3			4			5					
		Obs	Pred	Pred Out	Obs	Pred	Pred Out	Obs	Pred	Pred Out	Obs	Pred	Pred Out	Obs	Pred	Pred Out	Obs	Pred	Pred Out
Outside	*Thella jal*	0.2	0.2		0.1	0.1		0.8	0.9		4.2	6.1		1.3	2.1		6.5	9.3	
	Current jal (Stationary)	–	–		–	–		0.7	0.7		1.3	0.9		0.2	0.1		2.3	1.7	
	Ber jal	–	–		–	–		1.2	1.0		–	–		–	–		1.2	1.0	
	Daun	–	–		–	–		0.3	0.7		0.8	3.3		–	–		1.1	4.0	
	Veshal jal	–	–		–	–		0.7	0.7		1.9	1.9		–	–		2.6	2.6	
	Ucha	–	–		–	–		0.8	0.8		1.7	1.7		0.5	0.5		3.0	3.0	
	Jhaki jal	0.1	0.1		0.1	0.1		–	–		1.5	1.5		0.5	0.5		2.3	2.3	
	Hand fishing	–	–		–	–		–	–		0.9	0.9		0.2	0.2		1.1	1.1	
	Tukri	–	–		–	–		0.4	0.4		0.3	0.3		–	–		0.8	0.8	
	Doiar trap	–	–		–	–		–	–		–	–		–	–		–	–	
	Total	0.4	0.4		0.2	0.2		4.9	5.1		12.6	16.6		2.7	3.5		20.9	25.8	
	Standered Error		0.1			–			0.5			1.7			0.5			1.8	
Inside	*Thella jal*	0.2	0.2	0.2	–	–	–	3.4	3.4	1.4	11.3	10.0	4.8	17.7	14.8	5.2	32.7	28.4	11.7
	Current jal (Stationary)	0.2	0.2	0.2	0.3	0.3	0.1	2.1	2.1	0.9	3.0	3.8	1.9	3.1	3.6	1.2	8.8	10.0	4.3
	Ber jal	0.3	0.3	0.3	0.1	0.1	–	10.2	10.6	4.4	14.0	14.0	6.8	11.2	11.2	3.9	35.7	36.1	15.4
	Daun	–	–	–	0.5	0.5	0.2	5.7	5.3	2.2	6.8	5.7	2.8	4.6	4.6	1.6	17.6	16.2	6.8
	Veshal jal	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Ucha	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Jhaki jal	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Hand fishing	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Tukri	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Doiar trap	1.0	1.0	1.1	3.1	3.1	1.1	4.5	4.5	1.9	4.8	4.8	2.3	3.6	3.6	1.3	16.9	16.9	7.7
	Total	1.6	1.6	1.9	4.0	4.0	1.5	25.9	26.0	10.8	40.0	38.4	18.6	40.2	37.7	13.2	111.7	107.7	45.9
	Standered Error		0.2	0.5		0.8	0.6		1.6	0.9		2.9	1.7		3.5	1.2		4.9	2.4

Notes:

1. Total catches per unit area are tabulated by gear and season for sites inside and outside FCD/I projects. The columns labelled "obs" contain the catch per unit area calculated using observed CPUE and effort per unit area data. The columns labelled "Pred" contain the predicted catches per unit area. For inside sites, for example, these are calculated by multiplying the observed effort per unit area for inside sites by CPUE for inside sites predicted by the generalised linear model. The columns labelled "Pred Out" are only relevant for inside sites. These are calculated by multiplying the observed effort per unit area for inside sites by the predicted CPUE for outside sites for the same gear and season. This shows what catches per unit area would have been at inside sites had the inside CPUEs been the same as the outside CPUEs.
2. – denotes zero

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