BAY OF BENGAL PROGRAMME

BOBP/REP/35

Development of Small-Scale Fisheries

GCP/RAS/040/SWE

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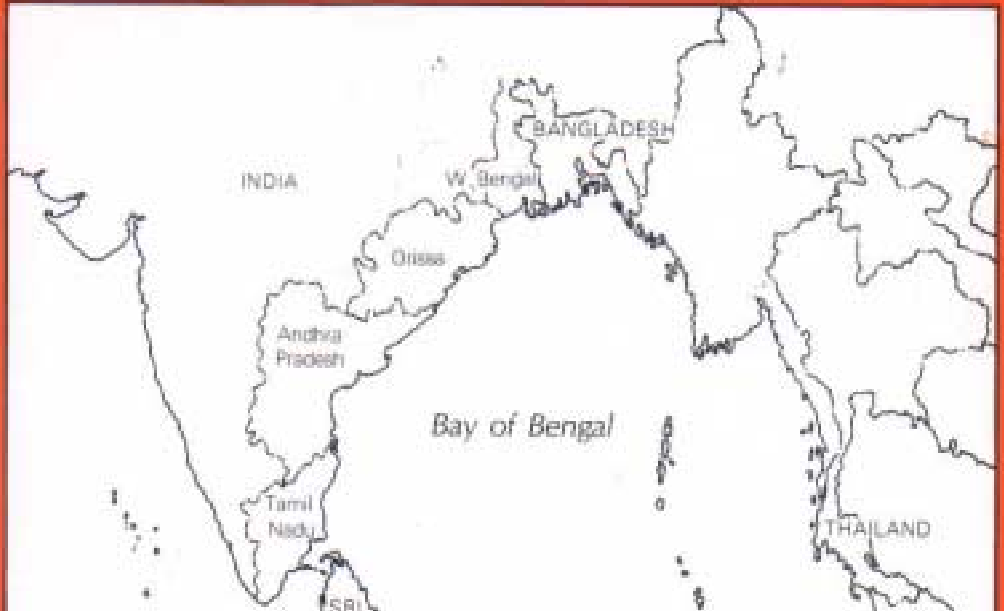

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BRACKISHWATER SHRIMP CULTURE DEMONSTRATION IN BANGLADESH

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This paper reports on three years of activities of a technology development-cum-demonstration project on integrated farming of brackishwater shrimp and fish-cum-rice, carried out both sequentially and concurrently, at Satkhira, Khulna district, in the south west of Bangladesh. The project improved on traditional culture practices of the region and also evolved new technologies, which if adopted would benefit the farmer by increasing his yield and the quality of his product. The project also suggested that, given appropriate modifications of culture practices and of certain environmental conditions, brackish water shrimp and fish-cum-rice culture is technically feasible.

The experiments were carried out in collaboration with the Directorate of Fisheries, Government of Bangladesh. Dr. A.N. Ghosh, BOBP Shrimp Culture Consultant, was associated with the project from 1982 to July 1984: he supervised the construction of the farm complex and provided technical guidance during the first one-and-a-half years of the culture operation (January 1983 - July 1984). The 1985 culture operations were designed by Dr. Mahmudul Karim, BOBP Aquaculturist, who left the project by end-March 1985. A study on shrimp seed collection was conducted by Mr. K. Larsson under a Swedish fellowship programme. Mr. Abul Kashem, Project Officer, BOBP was responsible for day-today supervision of the construction work and culture activities.

The scientific officers involved at various stages of the implementation of the project were Mr. Go!am Kibria, Mr. Habibur Rahman Khandker, Mr. Rezaul Kari, Mr. S.M. Jahangir Hossain and Mr. Noor Mohammad. Mr. Ataur Rahim and later Mr. A.H.A. Jalil, Deputy Director of Fisheries, Khulna Division, acted as Technical Liaison Officers to the project.

The Saikhira shrimp culture project, and this paper which reports on it, have been sponsored by the small-scale fisheries project of the Bay of Bengal Programme (BOBP). The project covers five countries in the region — Bangladesh, India, Malaysia, Sri Lanka and Thailand. Funded by SIDA (Swedish International Development Authority) and executed by the FAO (Food and Agriculture Organisation of the United Nations), the project seeks to develop, demonstrate and promote technologies and methodologies to improve the conditions of small-scale fisherfolk in member countries.

SUMMARY

Evolving out of a request from the Government of Bangladesh to the Bay of Bengal Programme of the FAO (BOBP) at its 3rd Advisory Committee Meeting held at Chittagong in 1978, a shrimp culture demonstration project went on line later in 1982 in Satkhira, Khulna district, southwest of Bangladesh.

The project set out to:

a. demonstrate improved methods of culture in order to increase the production of shrimp and fish of farmers;

b. monitor the existing conditions concerning water quality, recruitment of seed in time and quantity, and growth rate of shrimp in ponds;

c. transfer the information and technology to shrimp farmers in the area; and

d. identify the socio-economic support, over and above the technical know-how, for assisting the small farmers to utilize their own land and resources by direct participation in shrimp farming for better economic gains.

The project, a collaborative effort of BOBP and the Government of Bangladesh, established a farm-cum-research complex consisting of 11 experimental ponds, an agro-aquaculture field, water management systems, laboratory, office and storage buildings on a 20 ha site south of Satkhira town.

The main activities undertaken by the project included, inter alia.

a. development and demonstration of techniques of shrimp culture, separately and in combination with fin fish and rice;

b. training of fisheries officers, educated farmers and others in the practice of shrimp culture; and

c. a socio-economic survey to understand the status and needs of the small farmers in the project's hinterland and to estimate the impact of the project on them.

During the three years of culture, several techniques were evolved, revised and tested. These included.

a. Preparing the ponds prior to stocking, both to rid it of pests and to enhance the natural productivity of the ponds. Specifically, drying the pond bottom, ploughing, applying lime, manuring with cow dung and applying inorganic fertilizers were experimented with.

b. Pest control was attempted by screening the sluice gates with fine mesh screens designed not to reduce water exchange. Periodic castnetting, draining and hand picking, using the behaviour patterns of the pests to remove them and even frequent changes of pond water were attempted to reduce pests.

c. Ponds were selectively stocked.

d. Water quality was monitored to facilitate various management protocols.

e. Supplemental feeding using pelletized feeds.

1. Management of diseased or physiologically stressed fish populations.

Total yield from the project farm was 9.4 tonnes, of which exportable shrimp contributed 3 tonnes. The focus of the first two years was on getting the farm started; 1985 may be considered the first year of planned culture. In 1985, the total yield was 5.5 tonnes of which 1.9 tonnes was of exportable species; P. *Monodon* alone constituted 1.6 tonnes. The average production of P. *monodon* varied between 81 and 212 kg/ha.

Although there was an upward trend over time in the production in the project ponds, the yield was still very low compared to the efforts put in. The reasons for low production could not be clearly determined. The deterioration of water quality as a result of heavy siltation in rivers and canals of the area could be one important factor that suppressed growth, caused disease and subjected the organisms to stress, eventually increasing mortality. Competition from pests and predator losses could be another.

The pest control contrivances used by the project reduced intrusion of pests but not totally satisfactorily. Pest control techniques need further development and improvement.

Pelletized dry feed was prepared for the first time in Bangladesh for shrimp culture, using rice bran, fish meal, frog meal and animal viscera. Wheat flour was used as a binder. Severe shortage of raw materials of appropriate quality and quantity is anticipated for large scale feed preparation. This would call for development of pond fertilization techniques as an alternative or supplementary means of food supply.

Experiments with pond manuring and fertilization to enhance natural productivity were conducted for only one year. The response to pre-stocking pond preparation and post-stocking fertilization was encouraging. But further work on brackishwater pond fertiiization is necessary to generate more specific information for, extension purposes.

The project had intended to procure its own seed from the surrounding region but this proved difficult and seed was bought from traders. The increasing prices of *P. monodon* seed and the accelerated demand during the peak growing season, which coincides with the best catch period, suggested that seed availability may prove a constraint to culture expansion.

Brackishwater shrimp and fish was cultured along with paddy in the agro-aquaculture field. In 1983 and 1984, coupling of aquaculture and agriculture did not pose any problem but in 1985 the rice crop failed because environmental salinity did not drop below 5 ppt during the paddy transplantation season. The low-lying area of the AAF got silted and paddy cultivation in the field became increasingly difficult because higher than acceptable levels of water had to be maintained to keep the fish population alive.

The project organized two training courses up to end 1985. The training courses were designed for fishery officers and educated farmers and were held in three segments at different times of the years to ensure coverage of all aspects of culture practices. Detailed background papers relevant to each course were prepared and supplied to the trainees.

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1. INTRODUCTION

1.1 After Bangladesh attained independence in 1971, it launched two five-year plans to grapple with an array of socioeconomic problems. The fisheries sector focussed its efforts on boosting the production of food fish and of exportable shrimp, the objectives being better nutritional standards, higher employment and more foreign exchange earnings

1.2 Emphasis was laid on increasing the production of shrimp through both capture and culture fisheries, because of their demand in international markets, their lucrative price, and the environmental situation in Bangladesh which enables culture of the exportable species.

1.3 The scope for expanding production by capture was found to be limited, as exploratory surveys did not reveal any large shrimp grounds off the coast of Bangladesh. Further, the capital-intensive character of shrimp capture which is dependent on imported craft, gear, spare parts and fuel, inhibits expansion. So, while the national fleet and joint ventures did their best on the production front, the government increasingly concerned itself with culture.

1.4 There is a long tradition in Bangladesh of allowing the tidal waters to flood low lying fields, holding the water, and allowing the fish and shrimp which come in with the tide to grow. The production was naturally low and the productivity of the most desired species, P. monodon, according to farmers, rarely exceeded 30 kg/ha, contributing about 1520% of the total production. Such extensive culture can only be justified under conditions of low land cost and low land pressure; but Bangladesh's land was under tremendous pressure due to increasing population. The government was keen on increasing land productivity by developing area-specific technologies and diffusing the technology through demonstration and extension.

1.5 By the late 1970s Bangladesh already had about 24,000 ha of land under extensive shrimp culture, in the Cox's Bazaar region in the south-east, and in the Khulna region in the south-west. A wide brackishwater belt all along the coast flushed by appropriate tidal amplitudes, suitable water quality and salinity, a topography that allowed holding tidal waters in and a rich supply of shrimp seed in the estuaries and creeks — these factors influenced the government to expand and upgrade shrimp culture on a priority basis.

1.6 During the Third Advisory Committee Meeting of the small-scale fisheries project of the Bay of Bengal Programme (BOBP), held in Chittagong in 1978, the Government of Bangladesh requested BOBP's assistance to establish a pilot project to evolve and demonstrate improved methods of culturing shrimp. The BOBP in response requested FAO's Aquaculture Development and Coordinating Programme to assist in preparing a suitable project. Messrs H. Cook and U. Schmidt visited Bangladesh November-December 1979 and on the basis of their studies in the Cox's Bazaar area formulated a shrimp culture project with two components — one for the support of village fish farming, and the other to upgrade an existing demonstration farm at Chakoria Sundarbans in Cox's Bazaar. The Government of Bangladesh considered the recommendation and it was finally agreed that the project would be scaled down to one component — the demonstration farm — and that BOBP would support it.

1.7 In April/May 1981 BOBP arranged for a mission consisting of J.G. Broom, a private shrimp culture consultant and M. Karim from the BOBP, to finalize the project. The location of the project was changed from Chakoria Sundarbans to Satkhira in Khulna for technical reasons elaborated upon elsewhere in this report. The project, prepared for a three-year period, was formally approved by the Government of Bangladesh in 1982. The BOBP committed funds for buildings, ponds, electrification, equipment, supplies, training and expert inputs. The Government of Bangladesh provided 20 ha of land and counterpart staff. The project was the first organized attempt in Bangladesh to evolve and demonstrate technologies to improve the production of shrimp.

2. OBJECTIVES

2.1 The objectives of the project were to establish a technology development-cum-demonstration shrimp farm to:

a. demonstrate improved methods of culture, to increase production of shrimp and fish for farmers:

b. monitor existing conditions concerning water quality, recruitment of seed both in time and quantity, and growth rate of shrimp in ponds;

c. transfer this technology and information to shrimp farmers in the area;

d. identify the socioeconomic support over and above the technical know-how, needed to assist smali farmers to utilize their own land or resources by direct participation in shrimp farming for better economic gains.

2.2 The project hoped to go beyond technological innovations and improve the lot of the small farmer and fisherman of the region. The topography makes it technically and economically difficult to undertake aquaculture in individual small holdings. Small farmers lack the organization to cooperate and bring larger areas under culture. The result is that a few rich farmers or even outside operators manage to take all the private plots on yearly lease and organize the culture. While the lease rent is usually more than what the farmer can hope to earn from the one crop of saline resistant rice grown, there are several social and economic problems that seem to arise out of this particular mode of production. Further, due to the yearly nature of the lease there is no incentive to invest, the technology practised is essentially extensive and productivity is low. The project envisaged that given technical knowhow, soft credit and some organizational inputs, the small farmers and fishermen could organize themselves and participate directly in shrimp farming. It was hoped that better and more efficient culture practices would not only increase incomes but also generate employment. Socio-economic surveys and studies to understand the socio-economic situation of the farmers and to determine ways and means of helping them were planned. In particular the studies hoped to look into the feasibility of involving rural women in the effort.

2.3 For various reasons the dominant aspect of the project turned out to be the technical aspect, which was concerned with evolving and demonstrating improved and easily transferable brackishwater aquaculture methods, particularly for farming shrimp.

3. THE PROJECT AREA

3.1 The project farm is located in south-western Bangladesh in the district of Satkhira; the district headquarters can be reached from Dhaka by a half hour flight to Jessore and then a two hour drive on a narrow metalled road. The farm complex is a further five km south by unmetalled tract. Satkhira district has an area of 3,720 km^2 and a population of 1.36 million (1981) and until 1983 was part of the district of Khulna. Bordered on the west by the Indian state of West Bengal, the district of Satkhira constitutes a large area (1469 km^2) of the Sunderbans characterized by dense mangrove forests. Innumerable rivers and tidal creeks dissect the district, making waterways the most important transportation network.

3.2 The climate of the district is similar to that of other areas bordering the Bay with certain regional variations. The winter sets in early December and lasts till the middle of February. From mid-February it begins to get warm, and in April it becomes very hot; this continues until mid-June when temperatures drop with the coming of the monsoon. The rainy season continues till September. The temperature in the region varies from 18°C to 33°C; the humidity is high most of the year around.

3.3 The tidal amplitude along the Bangladesh coast is quite high while the coastal land is in general low lying; a wide coastal belt is therefore regularly flushed by high tides. Even though the project area is nearly 100 km up stream from the sea, the difference between the monthly average high high water level and the low low water level is nearly 2 m. January-February represents the period of minimal tidal variations; the maximum tidal levels are recorded normally during June-September (See Appendix 9).

3.4 The water salinity ranges from 2 to 18 ppt. January to May represents the higher salinity period, when 1 O-l 8 ppt salinity in the canal water is normal. Salinity starts declining as the rains begin and drops down to 3 ppt or even lower by August. The salinity again starts to rise by November and peaks in March-May.

3.5 The soil in the area is silty-clayey, often mixed with patches of sandy loam. Its pH varies from slightly acidic to slightly alkaline.

3.6 Under a coastal embankment project, which began in 1965, large areas of land have been enclosed, and reclaimed by the Water Development Board (WDB) — once called the Water and Power Development Authority (WAPDA) — by erecting massive dykes in order to prevent saline tidal water from inundating land potentially suitable for agriculture. Thus, extensive saline areas have been reclaimed for paddy cultivation. The brackishwater region in Satkhira is a monocrop area where agriculture is possible only during the low saline period. August to December. During January to July, agriculture is difficult due to high sub soil salinity and lack of adequate fresh water supply for irrigation; the salinity level in the rivers and canals during this period is high.

3.7 Instead of keeping their lands fallow during the dry, high salinity periods, farmers used to build earthen enclosures called ghers and flood them for aquaculture. The WDB dykes put an end to all this. But with increasing demand for shrimp and lucrative prices in the 1970s some of the farmers began to undertake shrimp and fish culture in the embanked areas, called polders. This activity was facilitated by the fact that several polders had become water logged due to poor drainage and it was no longer economical to grow paddy in them. By the late 1970s the shrimp culture area in Satkhira had already exceeded 5000 ha. The embankments which had been erected to keep out the saline waters in different circumstances turned out to be excellent for containing them.

3.8 When the BOBP project was established, the local farmers were practising an extensive form of fish and shrimp culture. The tidal waters were trapped inside embankments, and fish and shrimp coming in with the tides were allowed to grow. From talking to some of the farmers one got the impression that the average production per hectare was in the region of 300 kg of fish and shrimp. Of this, the high priced P. monodon accounted for a mere 10-15% (20-45 kg); various other lesser priced shrimp another 30%; and the rest fin fish. About 75% of the fin fish were predators which must have drastically reduced the production of shrimps (see Appendix 5 for predator species). The shrimp and fish culture season usually lasted from January to July. During the rains the land was used to grow one crop of transplanted Aman, a saline resistant variety of rice. Concurrent fish-cum-rice culture was practised in the narrow strips of land between the WDB embankments and the river banks.

4. THE FARM COMPLEX

Site selection

4.1 The site selection and project preparation mission visited two regions, Cox's Bazaar and Satkhira, as suggested by the Ministry of Fisheries and Livestock.

4.2 In Cox's Bazaar, two specific sites were considered. One at Chakoria, some three hours north-west of Cox's Bazaar by boat. It had many positive features but the high land elevation was an important negative factor. The area was covered by only 15-30 cm of water during spring tides. To be made suitable for a demonstration pond complex, the land would have to be excavated or water would have to be pumped to the higher elevation. Both these options would have been expensive and were not representative of the extensive type of culture that was being practised in Bangladesh. The other site was an oxbow lake near Cox's Bazaar town which had many positive features not the least of which was its proximity to a city and thereby its facilities. However, the lake had a central canal used for drainage of a nearby watershed during the monsoon season. The earthwork for levelling the bottom and the alternative channelling for watershed drainage would have been extensive and expensive. Water exchange would have been minimal because of the land elevation and there could have been some engine oil pollution problems from the heavy traffic of motorized boats in the area. Moreover, an oxbow lake was an unusual feature, unrepresentative of shrimp culture areas.

4.3 In the Satkhira region the mission saw three possible sites close to Ellar Char Village, seven km south of Satkhira. The sites were used sequentially for paddy-cum-shrimp farming, received tidal water from the Satkhira canal or the Marichop river. A preliminary topographical survey to determine the approximate area and relative land elevation was made at each site with the help of the WDB's survey personnel. The best of the three sites was a 28 ha private plot located in Mohishkur Mouja. The land elevation of the site was 1.6 — 1.8 m, while the tidal amplitudes during spring tides were 3.0 — 3.3 m, offering ideal conditions for the construction of tide-fed ponds. The soil was clayey in nature with good water retention capacity. The negative aspects of this area were its slight remoteness, 75 km from the nearest airport at Jessore and the relatively low salinity of the water (2-18 ppt) dropping to nearly zero during some periods of the year. The salinity, although rather low for some species of shrimp and fish, was ideal for the culture of P. monodon. The presence of Macrobrachium rosenbergi in the area indicated that, it was likely that the species could be grown in conjunction with paddy during the low saline or freshwater season. The most important factors were the large number of traditional shrimp farms in the vicinity of the project and the ideal tidal elevation conditions. The latter feature would allow the demonstration farm ponds to have an almost unlimited amount of water exchange, which would in turn allow a high stocking density. The large number of farms in the area would allow the technical people operating the demonstration project to respond directly to the farmer's problems and needs.

4.4 In view of the fact that a demonstration farm project had already been planned for Chakoria to serve the Cox's Bazaar region, the Ministry and the Directorate of Fisheries decided that a second demonstration farm project should be located in the Satkhira region. Considering the many technical advantages, it was further agreed that the Mohishkur site should be selected for locating the new shrimp demonstration farm with BOBP assistance (Appendix 1).

Layout

4.5 A detailed topographic survey of the selected site was conducted with the assistance of a local engineering consultancy firm. On the basis of the survey, the consultant (Broom) prepared a basic design and layout plan for the pond complex and the ancillary structures. Later, the layout plan and the engineering design were slightly modified after a year of operation by another consultant (Ghosh) to improve water management. The pond complex in its present form was completed early 1983. It consists of 11 ponds, an agro-aquaculture field, a supply-cumdrainage canal system, sluice gates, laboratory and office buildings and feed processing and guard sheds. Ten of the ponds are almost square-shaped experimental ponds of 0.8 ha each; a rectangular agro-aquaculture field is approximately 3 ha and the shallow pond (No. 11) for wild and incidental culture practice is 1.7 ha (see Appendix 2).

In the original plan, pond 11 along with its northern and eastern dykes did not exist. Instead, the whole area was a big catch basin meant to concentrate shrimp seed in it by allowing in high tide water repeatedly without screening, but screening the water while letting it out during the low tides. The catch basin did not satisfactorily serve the purpose of concentrating P. monodon seed. Moreover, the basin interfered with efficient water circulation and management in the pond complex. The greater part of the basin was therefore enclosed by erecting a dyke in the north and another in the east. This modification led to the creation of a large new pond (No. 1 1), and a well defined inlet/outlet canal enabling quicker filling and draining of the ponds and the agro-aquacuture field.

4.6 The pond complex was designed to be completely tide-fed.

Sluice Gates

4.7 Most of the pond sluice gates are of the masonry type, except for ponds 1, 5 and 11 in which wooden sluice gates are used (Appendix 3). All the wooden sluice gates have the same specifications; 8 m long, 1 m high mouth opening and 0.6 m width with grooves for shutters and screens. The masonry sluice gates are 5.15 x 1.2 x 0.6 m. The sluice gate to the agro-aquaculture fields was 5.15 x 1.2 x 1.2 m. At each end of the sluice gates there are at least two pairs of grooves for shutters and pest control screens fixed in wooden frames. Initially fall-board type shutters were used but were later replaced with draw board shutters. Each board of the former type of shutter was 15 cm in height. The purpose of using the fall-board shutters was to be able to supply clean water from the top layer of the incoming tide or discharge from the top layer of the pond any fresh water resulting from heavy precipitation. The used and stale water could be drained out from the bottom.

4.8 The four main sluice gates (two upper for drainage and two lower for supply of water), all of wood were of the same size, 20 x 1 x 1 m. Each sluice gate had one draw board shutter on either side; no screens were provided. Initially only two main sluice boxes were used, for both supply and drainage. Construction and installation of large wooden sluice gates required special skills possessed by only a few carpenters in the Khulna region. Four sides of the sluice gate were constructed and tarred separately at the pond site. Two passages each about 2 m were cut into the dyke and the passage bottoms were carefully levelled. A series of shallow and parallel grooves 2 m apart were made in the passage bottom; the grooves were perpendicular to the passage walls. Pieces of logs of the sundari tree were placed in the grooves so that the logs lay almost at the same level as the passage bottom. The logs served as a platform to support the weight of the sluice gate. The bottom part of the sluice box was first carried and placed on the platform, then the two sides were hinged with the bottom piece. The top piece **was** placed in position and locked with the two side walls. Both sluice boxes were placed at the same level, + 1.32 m. Sundari poles (5 m long and 15-22 cm in diameter) were thrust into the ground along the sides of each box to keep it secured against the high tidal impact. Sheet piling to prevent earth erosion and piping along the side and bottom of the sluice box were provided at both ends of each box. After installation, the gaps on the top of the sluice gate were earth-filled. The soil in front of the two ends of the sluice gates was thoroughly compacted, using brickbats to prevent scouring of the soil by incoming and outgoing currents. Two more main sluice boxes exclusively for water supply were constructed and installed at two slightly different levels, + 1.8 m and + 2.0 m in January 1984 on top of the original two.

Construction problems

4.9 The earthwork of the pond complex had to be completed in a hurry-to avoid a one year delay of culture trials. The step-by-step procedure normally recommended for constructing the dykes could not be followed. Lumps of earth were not broken down, and appropriate compaction of the various earth layers was not always provided for. This resulted in large-scale piping, tunnelling and potholes in the dykes soon after water intake and after a few heavy showers. The soil being loose, heavy erosion of particularly the northern and western dykes set in with the onset of strong south-easterly winds.

4.10 The pond complex suffered siltation problems from the very beginning. The large catch basin at the entrance to the main sluice gate was believed to be one of the important reasons why silt was deposited in the north-south distribution canal and in parts of the catch basin itself. However, remodelling of the basin (Section 4.5) did not improve the situation. The entire canal system was heavily silted up to a level higher than the pond bottom. Emptying of the ponds at the end of the culture operations became a problem. Repeated efforts were needed to cut out a narrow trench in the canal during low tide to drain out water little by little. Approximately 4,250 m^3 of silt was removed to make the ponds operational again.

4.11 The addition of two main sluice boxes at an upper level exclusively for water intake into the ponds was expected to reduce siltation. This was based on the assumption that top and column water in the canal would have less silt than the bottom water. So water intake through the upper sluice boxes would reduce silt intake while discharge of water through the lower sluice boxes would get rid of the accumulated silt. Unfortunately things did not workout as planned. Operating the sluice gates, especially the lower ones, required the workers in the project to get down into the water — something they were reluctant to do. So, they used the upper gates for intake and discharge of the water. And one never got to know how effective, if at all, a two tier gate system is in reducing siltation. Also, the post-sluice-box-installation-siltation in 1985 was very heavy; about 8,870 m^3 of silt was removed from the feeder canal and elsewhere.

Buildings

4.12 A semi-pucca* field laboratory shed with water and electrical fittings and 55 m^2 of floor space was constructed in 1983. Another semi-pucca shed (100 m^2 floor space) for office use and training purposes was constructed in the first half of 1985. Four guard sheds and a log house for watch and ward and a feed processing shed were also constructed. The project used two hired houses in town initially as office and laboratory but later as store, library, guest rooms, hostels for the trainees, etc.

* Pucca (colloquial) — Full-fledged, properly constructed.

Roads, electricity, telephones

4.13 A 200 meter section of the Satkhira-Ellachar road became impassable during the rainy season and had to repaired.

4.14 A diesel generator of 3 kw purchased for use on board boats in connection with fishing trials under a BOBP project in Cox's Bazaar area, was installed for electrification of the laboratory building. A few of the field points were also connected to the generator. Electric wiring at the pond complex was done during the first half of 1985. The connection to the main supply of the Power Development Board was delayed.

4.15 Efforts to exten d the city telephone line up to the project site were not successful. The nearest telephone was about 1.5 km from the project campus. A telephone could however be installed in one of the rented houses in town to facilitate communication.

costs

4.16 The total construction cost of the farm complex was Tk. 2.568 million of which the BOBP's share was Tk. 2.104 million. The breakdown of costs by major items is as follows:

(In Tk)

		BOBP	DOF
1.	Earthwork for pond complex	**590,000**	—
2.	Wooden main sluices (4)	240,000	—
3.	Wooden pond sluices (5)	122,500	—
4.	RCC pond sluices (9)	575500	—
5.	Lab shed with water and electrical fittings	252,000	—
6.	Office-cum-training shed	54,000	124,000
7.	Guard shed (4) log house	91,000	—
8.	Food, goat and generator sheds	10,000	—
9.	Diesel generator	42,000	—
10.	Electric wiring in the pond complex	—	340,000
11.	Road	120,000	—
12.	Tube well (2)	7,000	—
	Total	2,104,000	464,000

5. CULTURE PRACTICES

5.1 In order to put the development of culture practices into the proper perspective, one should understand the traditional mode of production and consider the project effort in two categories. The culture practices used in the project until 1984 were developmental in nature wherein various options and techniques were attempted and modified. It was essentially a period of learning for the project. The effort was based on the traditional practice and the objective was to increase production while retaining an extensive low-technology approach. During 1985 the culture effort moved towards intensification with increased inputs. In terms of production, the 1985 results should be considered the first results which might be indicative of the developed technology. The table on comparison of culture practices briefly lists the techniques used in culture by the farmers and by BOBP until 1984 and during 1985 while Appendix 7 gives a generalized protocol of culture activities that were used.

5.2 The seasonal pattern of culture at the BOBP project was evolved out of traditional practice and reflected it:

— From January to July, during the high salinity period, brackishwater shrimp and fish were cultured.

— From August to December, during the rains and the consequent low salinity period, a salt-resistant local variety of rice called transplanted Aman was grown.

Residual stocks of shrimp and fish, especially the euryhaline species which can tolerate low salinity conditions, were cultured in the paddies along with the rice.

In some farms, freshwater fish and shrimp were cultured concurrently with rice and some of the low saline tolerant brackishwater species.

Culture Practices

Major Techniques	Pre-Project (Traditional)	BOBP — 1983 — 1984	BOBP — during 1985
1. Pest control with screen	Not practised	Practised	Practised
2. Pond preparation by ploughing, liming, manuring and fertilization	Not practised	Very little effort	Major effort
3. Water exchange from the beginning of culture	Practised	Practised	No water exchange for first 2 months; introduction of about 10 cm of fresh tidal water during every spring tide cycle to compensate for seepage and evaporation, After 2 months water exchange in a regulated manner.
4. Supplementary feeding	Not practised	Occasional, sprinkling of rice bran & sometimes fish meal	More regular feeding, mostly in the form of dry pellets made from rice bran, fish meal, animal Viscera & wheat flour (as a binder).
5. Stocking	Entirely wild stocking	Selective stocking	Selective stocking; unscreened water allowed in some ponds during February and early March to encourage entry of *M. monoceros,* an exportable species; during Feb.-Mar., the more destructive predator animals, *Lates, Elentheronema,* etc. do not occur.
6. Nursery rearing	Not practised	Nursery rearing in bamboo screen pens which probably allowed the escape of the tiny post-larve	Nursery rearing in small mesh (1 mm) HDPE webbing material which retained the post-larvae more effectively.
7. Control of disease	Not practised	Liming and accelerated flushing with fresh tide water	Liming and accelerated flushing with fresh tide water.

Choice of species

5.3 Although many shrimp species occur in the region, four were regarded as having immediate culture importance because of their export potential, high market price and availability of seed in varying degrees. However, *P. monodon,* locally known as bagda chingri, was by far the most important species for culture in brackishwaters. *M.monoceros,* locally known as harina chingri or honne chingri, was a welcome intruder in the shrimp farm because of its export market, quick growth rate, prolific number and euryhaline nature. The species, however, is small in size, its average harvest size being only about 7 g.

A few numbers of autostocked P. indicus (shade chingri) were found to grow to 30 g size in 70 to 90 days. The price of this shrimp though at par with or even higher than P. monodon in most countries commanded only about 50% of the price of P. monodon in Bangladesh. Its seed was not collected by the seed collectors. The abundance of the species in Satkhira region was not studied. It showed up in the project ponds occasionally but was reported in much greater numbers from the ghers of higher salinity located further south e.g., Shymanagar, Munshiganj, etc. *M. rosenbergii* (known as golda chingri in Bengali), a giant shrimp, was also included in culture — though considered as a freshwater species — particularly during the low saline or freshwater cycle. *M. rosenbergii* was found to withstand even the higher saline regime during the dry season and bred in the ponds.

5.4 P. *monodon* and M. *rosenbergii* were selectively stocked; other shrimp were either autostocked or were deliberately allowed to enter some of the experimental ponds. Mullets, *Liza fade, L. parsia,* and Mugil *cephalus* of brackishwater origin were the most desirable fish species for polyculture with the shrimp. Because of their tolerance of freshwater conditions, their culture could be extended throughout the year. They were mostly autostocked, buf their populations in selected ponds were supplemented by artificial stocking. The natural seed supply of these species appeared to be reasonably good, but seed collection efforts in the private sector were rather limited. Except for occasional instances of supplemental stocking, private farms were entirely dependent on autostocking. Various carp such as *Labeo rohita, Catla catla* and *Ctenopharyngodon idella* were selectively stocked and cultured during the freshwater season along with paddy and the euryhaline fish and shrimp populations.

5.5 The project attempted both monoculture and polyculture. P. *monodon* was the prime choice for monoculture. In 1985 an attempt was made (in Pond No.3) to monoculture Tilapia during the low salinity August-November season. The agro-aquaculture field (AAF) was used for polyculture, sequentially with rice.

It was not possible to prevent the entry of pests. However, a pattern was noticed in pest abundance. Between January and March M. *monoceros* and mullets entered the ponds. Coincidentally, there were very few of the predators *L. Calcarifer* and *E. tetradactylum* during this period. The culture practices of 1985 were appropriately changed to take this pattern into consideration and exploit it. Except for Ponds 2, 7 and 8 which were screened and used for monoculture of *P. monodon,* all the other ponds had unscreened water input during the first quarter of 1985 to allow the entry of mullets and *M. monoceros* into enclosures.

Seed

5.6 The project had planned to collect the required *P. monodon* seed in and around the project site and from the nearby Marichop River, but prospecting indicated that the availability was low. All seed for the project was purchased from commercial traders who collected it from the southern parts of Satkhira district.

5.7 Extensive commercial collection of seeds is carried out in all the major rivers and canals of Satkhira, Debhata, Assasuni, Kaligonj and Shyamnagar upzilas in Satkhira district. The main seed collection rivers are the Kalindi, Kholpetua and Kapotakshi.

5.8 Three types of collecting nets are used by local farmers and fishermen to collect seed (See Appendix 4). The Behundi net is a set bagnet while Baksho Jal and Thela Jal are mobile drag/push nets. The nets are made of HDPE of 1 mm mesh size. The net material is brought in by traders (who purchase them in India) and sold locally for approximately Tk 8-13 per yard. The nets are sewn by local tailors and depending on the size, the set bagnets cost about Tk 200-400 a piece while the mobile nets cost Tk 20-30 a piece.

5.9 P. monodon seed, the only seed commercially collected, was available in varying quantities in the rivers where the salinity was above 5 ppt. The intensity of collection was naturally affected by the stocking demand of the farms. Stocking time, again, was dependent on tidal pattern and salinity. During early 1980s shrimp culture was restricted to the northern parts of Satkhira district where salinity conditions are generally lower, restricting culture to January-July. So the peak demand occurs around February. As shrimp culture was extended to the southern parts of the district where salinity conditions allow longer periods of culture, the peak seed demand period also increased its span. The relative abundance of seed is indicated by the collection/net/day shown below. The data is based on interviews with seed collectors and should be viewed as indicative only.

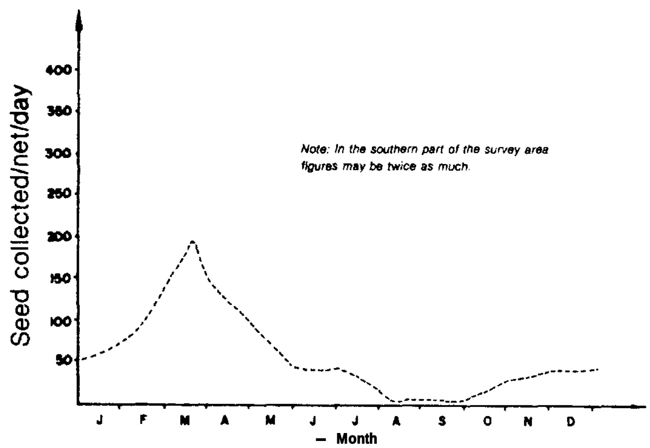

Fig. 1: Number of seed collected/net/day

Most of the seed was collected during the new and full moon phases of each month. Seed collection is a daytime activity for practical reasons as the light helps in sorting the species. But night collection is undertaken during the peak season. Set bagnets placed close to shore are operated during high tides while those mid-stream are operated all the time; mobile nets are used during the low tides. The catch is removed from set bagnets every 20-30 min.; the frequency is higher with the mobile gear.

5.10 The seed and debris were usually poured into a five litre earthen jar. The segregation takes place either close to the river or at fixed places above the high water mark. Small portions of the catch are poured into a white enamel dish and the dark coloured P.monodon seed of 10-20 mm length sorted out with a mussel shell. P.monodon consists of usually less than one per cent of the catch and the remaining fry of various shrimp and finfish are left to die on the river bank.

5.11 From the collection centres, the seed is transported by foot, bicycle, bus and boat. Aluminium and earthen jars of various sizes are used for seed transportation. When transported by foot split bamboo-stakes with two 12-16 litre containers suspended at each end are used, balanced on the shoulder. Bicycles have one or two containers of the same size tied at the rear. The water in the containers is changed every 4-5 hours, when available. The mortality during Nov-Feb (cold season) was reported to be less than 10% and during the rest of the year upto 20%.

5.12 Between the collector in the field and the shrimp farmer there were as many as three levels of middle men. Seed collected close to farms were often sold directly to the farmers by the collectors. But in most instances the collectors sold their catch to traders who moved the stock up the market chain, the price increasing at every transaction. Local farmers felt that there were at least a thousand persons involved in trading seed in Satkhira district alone.

5.13 Rapidly increasing prices for P.monodon seed were noted in the district during the early 1980s. The seed price went up from Tk 40-60 per thousand post larvae of 10 mm size in 1980 to Tk 400 per thousand by 1985. Every year, the seed price peaked in Feb.-March, this being the busiest stocking period throughout the district. Price for *P. monodon* seed paid at a few collection sites during 1985 is indicative of the price trend. It is interesting to note that collection rate and price peak at about the same time, suggesting that the demand accelerates enough during the short stocking period to keep the price up even during the supply periods.

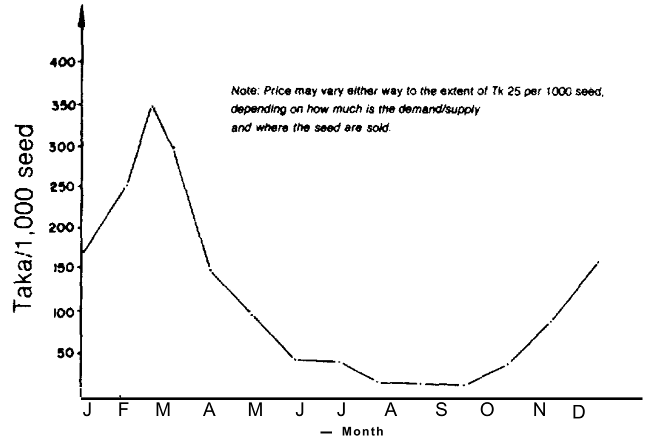

Fig. 2 Price structure of ***P.*** *monodon* seed in Satkhira, 1985.

5.14 An estimated 20,000-25,000 people were engaged in seed collection in Satkhira district during the peak season in 1985. This figure was calculated by multiplying the observed average numbers of collectors per mile of river with the total length of the rivers in the area. Many of the people involved in collecting seed were landless labourers living close to the rivers. During the peak season, whole families of men, women and children were found collecting seed. The mobile nets were operated by teenaged boys and girls while Behundi nets were generally operated by entire families. Seed transportation in bulk and marketing were the functions of adult males. Casual interviews by project staff with collectors suggest that seed collection pays well. Even women and children are able to earn as much as Tk 100-150 per day during the short peak season.

Pond preparation and fertilization

5.15 In 1983, the first year of the project, no special measures were taken for pond preparation. The ponds and the field were filled as soon as the temporary main water control structure was installed. In 1984 the ponds were drained and dried prior to filling. In 1985, the pond preparations consisted of a series of activities.

— Complete draining by gravity flow and by pumping at the end of November. The draining process was greatly hindered by heavy siltation in the feeder canal.
— Erection of a temporary dyke in front of the main sluice gate to prevent high tide water from entering the pond complex during maintenance and pond preparation activities.
— Removal of silt.
— Sun drying the pond bottoms until cracking of soil.
— Ploughing: ponds 2,3,4,7,8, and 10 were ploughed entirely and pond 11 in parts to a depth of 7-12 cm; ponds 1,5,6, and 9 were not ploughed.
— Liming: all the 11 ponds were limed at the rate of about 200 kg per pond. Calcium oxide (CaO) was first slaked into dust, which was then broadcast all over the pond bottom. In all the ponds, except 1 and 9, liming was completed during 27 December to 3 January, the other two ponds were limed on 2 February.
— Cow dung (1,500) kg was applied to each pond in several heaps.
— Bamboo twigs, plum branches, coconut fronds, etc. were planted in the bottom along the pond berms to provide additional substrate and shelter for the shrimp.
— The AAF was never subject to any special treatment except drying the field until the soil cracked. In 1985, the field had lots of long paddy stumps deliberately left behind at the end of the paddy harvest in December 1984, to increase the natural fertility of the field.

5.16 Use of inorganic fertilizers: In the beginning, no inorganic fertilizer was used. A systematic chemical analysis conducted in early 1985 indicated that the pond soil was deficient in available nitrogen, phosphorus and pottasium for paddy production. Such soils are also unlikely to sustain primary productivity in an aquatic environment. Attempts were therefore made to enrich the soil for algae production by supplying three inorganic fertilizers: triple super phosphate (TSP), urea and muriate of potash. It was the intention to promote production of blue-green algae mat, called lab lab, on the shallow berms, and to produce phytoplankton in deeper waters. Stress was laid on lab lab production for the first few months when the pond salinity was on the higher side. Low salinity being unsuitable for the lab lab growth, the focus was shifted to the production of phytoplankton during low salinity periods to support zooplankton which provided food to the shrimp. Attempts were also made to produce filamentous algae in limited quantities; these not only directly provide food to the shrimp but also harbour a rich population of micro-organisms that form food for the shrimp. In view of the different nutritional requirements for the various types of food organisms, the NP ratio was adjusted — a higher ratio of nitrogen (10-2:1) for lab lab, and a higher percentage of phosphorous (n:p:2-3:1) to promote growth of phytoplankton and filamentous algae. *Prophyrosiphon lyngbya, Spirogyra* and *fnteromorpha sp* were the common filamentous algae.

5.17 Water was introduced into the ponds through small-mesh screens having 16-34 meshes per 2.5 cm length. About 0.7-1.0 m depth was maintained in the ponds, though in pond 11 which was heavily silted up, the water depth was much lower. In the AAF, the maximum depth nowhere exceeded 75 cm but most parts were not deeper than 30-40 cm. In 1985 about 15 cm of water was initially introduced and maintained in the pond for about seven days to stimulate growth of benthic flora and fauna: then the water level was increased to 50 cm.

5.18 Nursery Manegsment

The farm did not have any separate nursery ponds. In the beginning, nursery rearing was practised in small round pens made of split bamboo screens; the pens were fixed in the middle of some selected ponds and in the paddy field. Dry branches of bamboo and plum were placed in the pens to provide shelter and attachment substrata to the post-larvae. However, many of the tiny post-larvae escaped through the spaces between the bamboo splits. Later two types of pens were used; one type 20 m x 20 m x 1 m was made of high density polyethylene (HDPE) webbing material of 1 mm mesh sizes; the other type 14 x 14 x 2 m size was made of closely woven bamboo splits. The first type was used in ponds 5,8 and 10; the second type in ponds 2 and 3.

5.19 To fix the HDPE pen wall, a narrow trench or furrow 12-15 cm deep was dug with the help of a metallic furrower (locally called shabol). The bottom line of the pen wall was then placed in the trench and the earth returned and compacted. The top of the pen wall was laced with horizontal bars tied to a series of bamboo posts. The pen walls were installed when the pond bottom was firm but not completely dry. The pens were located in the pond corners instead of in the middle to economize on webbing bamboo screens and other related materials. Another reason for locating the nursery pens in the corners was to include in the pen grassy berms providing attachment substrata and shelter for the *P. monodon* post-larvae and also to facilitate feeding, watching and growth sampling from the shore without getting into water. Bundles of grass, twigs and straw were also planted in the pond bottom to provide additional substrata and shelter.

5.20 In the AAF, following paddy cropping in mid-December, two temporary nursery ponds, one in the north and the other in the southeast, were constructed. The southern pond measured about 0.5 ha of shallow area with 0.6 m depth. The northern pond was about 0.2 ha with a central and a horizontal burrow pit from where earth had been removed for repairing the dykes. In the case of the southern nursery pond four pest control screens were fixed in the dykes about 30 cm above the ground level in the deeper region. Liming and manuring were done as in the grow out ponds; ploughing was omitted for lack of time.

Stocking

5.21 All the seed was purchased from seed traders who on prior contract delivered the seed at the farm site, usually at dusk. The seed was counted and transferred to nursery pens or directly into the grow out ponds For counting, some water along with the seed was poured from the transportation container into a white enamelled flat dish. Another dish containing some water taken from the stocking pond was kept at hand. With the help of a mussel shell, the seed was counted and transferred from the first dish to the second dish and then to the nursery pens. No special technique was adopted to gradually acclimatize the seed to the salinity and temperature of the pond water. The rate of post-larvae stocking in the nursery pens varied between 10,000 and 20,000 which amounted to 250,000 — 500,000 post-larvae per ha; in the two AAF nursery ponds 100,000 seed were stocked.

5.22 Nursery rearing continued for about six weeks; during this period the 10mm post-larvae reached 30-50 mm sizes. Stocking of rearing ponds was carried out with nursery reared P.monodon juveniles or by stocking of post-larvae direct from the seed traders. To release the nursery reared seed, the pen walls were simply lifted. In the AAF, the nursery ponds screens were removed. Introduction of fresh tide water stimulated the juveniles to come out of the nursery ponds and disperse into the field. The rate of post-larval stocking in the ponds directly or in the nursery pens were taken to be the stocking rate for grow out ponds and field.

5.23 During the low saline or fresh water season, juveniles of *M.rosenbergii* and fingerlings of three species of carp — C.catla, L.rohita and *Ctenopharyngodon* idella — were stocked in small numbers in the AAF and selected ponds. In 1983, *L.rohita* and *C.idella* were stocked. In 1985, carp was not stocked at all due to continuously high salinity in the ponds. Instead of carp, *Oreochromis* mossambica (Tilapia) was stocked in pond 3 and in the AAF. The carp fry at stocking were 50-80 cm in size. *M.rosenbergii* were 30-50 mm size. *Tilapia* fry size was in the range of 15-25 mm.

Feed

5 24 For the first year and a half, aquaculture supplemental feed was not used except for an occasional application of rice bran in some ponds. In the second half (August-December) of 1984, supplemental feed in the form of rice bran and chopped or crushed freshwater snails collected from nearby paddy fields was provided. Although no definite information on their abundance was available, the snail population in the area did not appear to be big enough to sustain a substantial culture fishery. The rice bran available in Satkhira was of poor quality; it had more husk than bran or broken rice.

In 1985, feed preparation and feeding were attempted on a more regular basis. Two hand grinders were procured and used for preparing pellet feed using animal viscera, fish and frog as sources of animal protein, and rice bran and wheat flour as sources of carbohydrate. The wheat flour also acted as a binder. The following combinations were tried.

— animal viscera (60%), rice bran (20%) and wheat flour (20%)

— ‘A’ grade fishmeal (40%) rice bran (35%) and wheat flour (25%)

Efforts were made to prepare at least 40 kg of wet pellets everyday and dry them in the sun. The project also endeavoured to maintain an inventory of about 200-300 kg of dry pellets as a provision against lean days. This was the first time that dry pellet feed for shrimp was formulated in Bangladesh. The feeding rate was 1-3% of the body weight of the shrimp. Artificial feeding started about two weeks afier stocking of post-larvae, depending on the pond fertility and growth of the post-larvae. Dry or half dry pellets were thrown along the edge of the grassy berm sometime before sunset when the shrimp became active and started grazing. Slight moistening of the dry pellets helped the feed to sink quickly.

Pest Control

5.26 Thorough drying, ploughing and application of lime killed most of the pest organisms. Contamination of the ponds with myriads of eggs and larvae of aquatic organisms was a severe problem. Water was therefore passed through fine-mesh screens. These fine meshes got quickly clogged This slowed down the water velocity and built up water pressure on the screens which often gave way. To prevent this, the screens had to be continuously brushed by hand during water exchange. Using screens with bigger mesh sizes (16-24 meshes per 25 mm length) did not resolve the problem of clogging. Complete elimination of pests was not possible. They could not be easily detected until they grew bigger. Metapenaeid shrimp occupying the same ecological niche as P. monodon occurred in large numbers. The most important predators entering the ponds were Glossogobius giuris and Mystus moda, appearing in Satkhira canal early in January. Both species are basically bottom dwellers and G. *giuris* grows very fast during the initial few months and possibly accounts for substantial loss of shrimp. The role of Mystus in predating upon P. monodon was questionable. Appendix 5 shows most of the predators which occurred in the ponds.

5.27 Various techniques were used to remove or reduce the number of pest organisms in the ponds.

Trapping: The behaviour pattern of shrimp and crabs, of swimming against the incoming high tide, was taken advantage of. A bamboo split trap (Dhosha) was placed at the sluice gate mouth and the metapenaeid shrimp and crabs were trapped during water intake. The pests were periodically removed from the traps and desired species were returned to the pond.

Castnetting: Pests were lured to a particular site using rice bran as bait, and castnetted.

Dragnetting: Small-mesh (10 mm) drag net was found effective, but its use was discouraged as its operation disturbed the pond bottom ecology.

5.28 Storks and snakes posed unique problems. The birds were found on the pond berms or shallow parts of the nursery ponds. The birds removed a large number of juvenile shrimp every day. Snakes were also observed at each sluice gate opening in the AAF nursery ponds. The snakes preyed on shrimp which gathered at the sluice gate screens.

5.29 A thick mat of a finely branched coelenterate (not identified) grew profusely on the bamboo screens. The mats were periodically removed with a metal scraper and a hard brush. A submerged floating and branched angiospermic weed *Najas* sp., having finely serrated narrow leaves was accidentally introduced into Pond 3 in 1985. The weed grew very fast and almost choked the pond within two months. It was possible to keep the weed population down by manually removing the weed but not to completely eradicate it. Spreading of the weed to other ponds could however be checked by adopting necessary precautions.

Water Management

5.30 About 30-40% of water in the ponds was exchanged over 3-5 days during each spring tide cycle. From November to February, water exchange was a problem, the tidal amplitude being characteristically low in the region.

5.31 In order to ensure utilization of manure and fertilizer, water was introduced in phases, 50 cm of water to begin with. This depth of water was adequate for the post-larval shrimp nursery rearing. The purpose of starting the culture with low water was two-fold:

- lower requirement of fertilizer
- opportunities for introducing fresh tide water in several instalments, corresponding to 3-4 spring tide cycles, until the pond water reached its full depth of about a metre. During the period, water was introduced into the pond but not let out.

5.32 Subsequent to initial filling, fertilizer was applied at a reduced rate, half to one-fourth of the original dose every fortnight. Subsequent to the nursery phase, water exchange was provided monthly or fortnightly to make the best use of the fertilizer used. During the rearing period, fertilizer application rate was reduced; 1/2-1/4 of the original dosage depending on the pond conditions. Once the shrimp had grown above 10 g, the frequency of fertilization was reduced with the intensification of artificial feeding; 30-40% water exchange was provided to adequately flush the ponds of metabolic matter during each spring tide. Efforts were made to improve water quality in the northern part of the agro-aquaculture field by creating a higher head in pond No. 6 and then letting the water flow into the field through a small sluice gate. A similar effort was made to develop a flow-through system in pond No. 3 by installing a small sluice gate connecting the pond with the WDB canal. The old and used up water in the far end of the pond could be discharged into the WDB canal. However. these sluice gates were used only occasionally.

Harvesting

5.33 Although P.monodon was by far the most important culture species, there were several other species of shrimp and fin fish desired or undesired in the culture system which substantially contributed to the farm income. Different species grew at different rates and became marketable at different times. In fertile ponds, a proportion of the P.monodon stock reached 30 g size in 60 to 70 days while the rest of the stock took much longer to reach good grades. This type of growth pattern require selective harvesting of the bigger individuals without disturbing the undersized ones or natural food organisms growing on the pond bottom. A portion of *M.monoceros* grew to exportable size (7-8 g) in just 4-6 weeks; a large quantity of this shrimp could be harvested before *P.monodon* harvesting started. Liza *parsia* and L.tade, the most favoured fin fish species for polyculture with the shrimp, grew to good harvestable size by September or October. Other species of fish required a longer time to reach commercial size. At the moulting stage, which was prevalent during the second and fourth quarters of the lunar cycle, the price of shrimp drastically dropped and so harvesting had to be avoided.

5.34 Grown-up shrimp and mullets are strongly attracted by the incoming high tidal water during the new moon and full moon periods. By letting in fresh tidal water, the shrimp and mullet were concentrated in a small enclosed area 'Goi' at the supply-cumdrainage sluice of the AAF (Appendix 6). The entrance to the goi was screened with bamboo splits (Pata) having one or more openings with flaps which could be closed at the end of a high tide to prevent the shrimp and fish from escaping. A series of traps were set outside the goi along the screen keeping the goi mouth free. The spaces between the bamboo splits of the goi screen and of the traps were wide enough for the undersized shrimp and fish to escape, but close enough to retain the marketable shrimp and fish. Big crabs with their strong chelipeds often caused considerable damage to the trapped shrimp and fish. In order to avoid the problem, the traps were lifted and emptied as often as necessary. The marketable shrimp and fish were transferred in live condition to bamboo baskets which were kept immersed in water. Smaller fish and shrimp were returned to the ponds for futher growth. The act of concentrating the shrimp and fish in the goi was done mostly during night tides. The shrimp and fish from the goi could be scooped, castnetted or handpicked for selling as and when convenient. Selling of the shrimp was done mostly in the morning.

For harvesting the ponds, bamboo traps which fitted more or less exactly into the pond sluices were used. One trap was used at a time. The trap was placed on the pond side of the sluice gate mouth and the other side of the sluice was screened. The trap could be operated without getting into the water. During the first two years, a goi made of bamboo screen with a layer of velon screening material was used in each pond. Gois are expensive and cumbersome to use in ponds. The workers had' to do the unpleasant job of getting into water every time to set and empty the traps.

In order to effectively apply the technique of concentrating and trapping against the high tidal flow, it was necessary to reduce the pond water level during the low tide and permit the high tide water to enter the pond with good velocity. A good head difference between the water levels inside and outside the pond was therefore created before introducing the water.

5.35 Moistened rice bran, minced or chopped snail meat, etc. were scattered at certain per-fixed points where the pond bottom was flat and not too deep to aggregate the shrimp. After waiting for 10-15 minutes. the areas were castnetted. The efforts were significantly more rewarding in the morning or evening when the shrimp were active.

5.36 The culture cycle was normally completed by end-November or early December and paddy was harvested by mid-December. Towards the end of the aquaculture operation, water was drained out normally at night to a safe minimum level, and harvesting of the residual stocks was attempted by intensive group castnetting and dipnetting early in the morning. The fishing operations stopped before the peak marketing hour was over. Some fresh canal water was introduced in the ponds and the fields to reduce environmental stress. At night, the water level was again reduced and the fishing process was repeated the next morning. The ponds and the fields were eventually completely drained out and intensive handpicking was employed for complete harvesting. A few trenches converging towards the sluice gates facilitated quick draining of the water and concentration of the shrimp and fish at the sluice gates. Draining out water through the usual screen was a very slow process. During the final harvesting phase, screening of incoming water was not at all required. A bagnet made of 12 mm mesh knotless nylon webbing was used in the AAF sluice with very satisfactory results. The net laced with a wooden frame was 2.5 m long and had a codend that could be easily closed and opened with a tie rope. The water could be quickly drained cut through the net. The discharge of water was so controlled that the flow of water was sufficiently strong to effectively pull the shrimp and fish into the bag but not so strong as to damage the quality of the catch by excessive water pressure. The water flow was suitably regulated by adjusting the sluice shutter. The collected catch was periodically removed by untying the codend. Complete harvesting of a pond normally took 2-4 days. It took several days to complete harvesting of the AAF. Paddy was harvested soon after the shrimp and fish harvesting was over.

5.37 Recovery from the feeder canal: Large quantities of P.monodon and *Liza* spp. and of course, other shrimp and fish were harvested from the feeder canal. Most of these animals apparently escaped from the various ponds and the AAF through the defective sluice screening systems and shutters. Many of the stocked animals probably also escaped through crab holes or piping in the pond dykes and around the wooden sluices. One fairly strong and closely woven barricade screen (locally called baddha pata) made of bamboo splits was installed in the feeder canal near the main water control structure to retain the escaped animals; these animals were periodically harvested by trapping, castnetting and lastly by handpicking after complete draining. In 1985, 154 kg of P.monodon, 65 kg of M.monoceros, 69 kg of Liza spp., 43 kg of other fin fish and 125 kg of miscellaneous shrimp which otherwise would have been lost through the main sluice, were captured. The sale proceeds from the recovered shrimp and fish amounted to Tk. 29,000 representing 9.5% of the total gross income from the farm during the year.

Physico-Chemical Parameters

5.38 The physico-chemical parameters of the farm ponds have been recorded since March 1983.

5.39 The monthly average tide data for (1983-85) rainfall and canal salinity data for (1983-85) are in Appendices 9 & 10. Excessive rainfall in 1984 almost reduced the canal salinity to zero for a period of time; during the period, attempts were made to maintain the pond salinity as high as possible by stopping water exchange. A typical pond salinity pattern (of 1985) is given in Appendix 11. The water surface temperature of pond 10 as recorded at 1000 hrs is also indicated in Appendix 11. The pH in the unlimed ponds normally varied between 7-8. The pH temporarily shot up to 9 to 9.5 in ponds just after treatment with lime which was done to control fungal infections of the shrimp. The DO range was 5-13 ppm, but most of the time the value remained between 8 and 10 ppm.

5.40 A number of soil samples (up to 22 cm deep) collected from various locations in the project pond complex and from two private ponds, one in Satkhira Upazila and the other in Shyam Nagar Upazila, were analyzed in the Bangladesh Agricultural Research Institute (BARI). The soil pH was 6.5-7.5 (Appendix 12) — an ideal range for aquaculture. However the BARI study suggested that the levels of nitrogen, phosphorus, potassium, manganese and zinc were lower than the optimum levels desired for good production of paddy.

6. PRODUCTION RESULTS

6.1 The total production of shrimp and fish from the farm complex for the three culture years 1983-85 is summarized in Table 1. The two initial years 1983-84 have to be regarded as a trial period when strong efforts were made to make the project operational.

Table 1: Summary of production results, 1983-85

Cultured species	1983 Kg	1983 Tk	1984 Kg	1984 Tk	1985 Kg	1985 Tk
Exportable shrimp (P.monodon, *M.monoceros, P.indicus)*	659	23,630	412	25,877	1,921	253,817
Other Shrimp	397	4,440	709	8,146	1,640	19,444
Fin Fish	352	4,930	1,361	18,409	2,000	31,519
Total	1,408	33,000	2,482	52,432	5,561	304,780

Two factors, amongst others, could possibly explain the poor performance of the first year of culture (Dr. A.N. Ghosh, unpublished data):

1. The ponds were excavated and this resulted in the top soil being removed. This in turn could have affected pond bottom ecology and the natural productivity of the ponds.
2. The water exchange was insufficient for various reasons.

The culture activities were begun with staff who had no real experience of shrimp culture, and while they were being trained on the job, it was difficult to assure the level of management required for successful cultures.

In the second year, 1984, an abrupt fall of salinity in the Satkhira canal, created by heavy rains in June, proved detrimental to the culture. As Appendix 10 shows, the canal salinity dropped from 17 ppt to nearly zero ppt in June; and then remained low, never exceeding 4 ppt during the year. Water exchange in the pond complex was temporarily stopped to maintain the pond salinity. But frequent showers did lower the salinity, which stabilized around 6-7 ppt. Although this salinity level is considered suitable for brackishwater aquaculture, a lack of exchange might have affected the physiology, survival and growth of the shrimp.

The survival rate of the P.monodon was still very poor and the harvest of mullets during the year was also much lower than expected. Recovery of 154 kg of P.monodon and 69 kg of mullets from the feeder canal, not stocked artificially, suggests that juveniles from the stocked ponds may have found their way out.

6.2. 1985 may be considered the first year of planned culture under stable project conditions with trained personnel. The stocking and yield for 1985 is shown in Table 2. The production results, both during the high saline and low saline periods, are presented in Table 3.

Table 2: Stocking & Yield, 1985

	1	2	3	4	5	6	7	8	9	10	11	AAF	WDB	Feeder Canal	Total
Pond area (ha)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.7	3.0	0.4		**13.1**
Stocking (nos)															
P.monodon (a)	10.800	10.200	11.000	11.800	12.600	10.000	15.200	20.500	9.200	17.400	16.000	99.600	2.200		246600
(b)	10500	5300	100	900	9300	1100	5000	4600	7400	200	-	44000			22400
M.rosenbergii	auto stocking & carryovers														
Mullet (L Parsia)	14.000	10.400	7.600	8.200	-	5.200	11.700	7.000	3.000	13000	1.700	10.000			93200
Production (kg)															
P.monodon	102	136	104	120	73	71	124	170	88	58	64	289	82	154	**1.595**
Mrosenbergrii	5	3	5	2	3	0.5	1	2	8	1	1	21	1	**2**	55
Misc. Shrimp	53	68	79	73	128	107	70	144	84	206	111	492	60	190	1.910
Mullet (L Parsia)	63	9	19	59	5	20	28	7	9	7	70	547	17	69	929
Other fish	216	51	71	89	48	62	45	17	48	20	75	299	35	48	1.069
Final average wt of *P monodon* (g)	22	24	21	22	20	25	21	23	23	26	21	20	26		
Survival of *P.monodon* (%)	22	37	30	44	11	28	29	29	23	15	13	10	55		
Production of P.monodon (Kg/ha)	127	170	130	150	91	89	155	212	110	**85**	38	96	81		

* (a) First stocking-February (23/1 - 23/2)
(b) Second stocking - May (2914)

Table 3: Production Results by Species & Culture Season, 1985

Species	Feb.-July		Aug.-Dec.		Total 1985	
	Kg.	Value	Kg.	Value	Kg.	Value (Tk)
P.monodon	1,259	192,836	336	44,215	1,595	237,051
P.indicus	26	1.860	2	104	28	1,964
M. rosenbergii	620	396	47	4,988	53	5,384
M. monoceros	228	3,786	17	1,182	245	9,418
Tot. export shrimp	1,519	203,878	402	49,939	1,921	253,817
Misc. Shrimp	457	5,922	1,183	13,521	1,640	19,444
All Shrimp	1,976	209,800	1,585	63,460	3,561	273,261
Mullet	—	—	782	14,904	782	14,904
Carp	—	—	—	—	—	—
Tilapia	—	—	149	1,742	149	1,742
Other fish	207	2,801	862	12,072	1,060	14,873
All fish	207	2,801	1,793	28,718	2,000	31,519
Total shrimp, fish	2,183	212,601	3,378	92,178	5,561	304,780

The value earned from the production of exportable shrimps during the high saline period was 67% of the total sale from the farm. It is also clear from the table that the value of the whole year's production of *P.monodon* contributed 78% of the sale from the farm. This reinforces the local belief that *P.monodon* is the only economically important cultured species at the farm and in the region. The productivity of *P.monodon* in the ten identical 0.8 ha ponds with similar culture practices ranged from 85 to 212 kg/ha. The average productivity in these ponds was 132 kg/ha and was much less than expected. The average surviva! rate was 21% compared with the reported local farm survival rates of approximately 10%. *P.monodon* at harvest had an average weight of 23 g and contributed 29% of the total harvest weight from these ten ponds.

A partial harvest was carried out from March 10 to April 24 before the second stocking in May. The results are shown in Table 4.

Table 4: Growth of P.monodon — from first stocking till 24 April 1985

Pond No.	Stocking Date	Stocking rate/ha	Harvested quantity (kg)	Average weight (g)
1	11/2	13,500	24.5	23.1
2	26/1	12,700	25.7	24.7
3	23/1	13,700	28.8	25.0
4	06/2	14,700	30.9	25.5
5	10/2	15,700	31.8	37.6
6	30/1	12,500	13.7	23.9
7	03/2	19,000	34.4	23.1
8	28/1	25,600	49.0	23.4
9	14/2	11,600	3.9	26.2
10	06/2	21,800	5.5	21.4
11	06/2	9,400	—	—
AAF	12/2	33,000	1.4	24.4
WDBC	26/2	5,500	0.4	19.2
Feeder Canal	—	—	24.9*	21 .1
Total harvested (kg)	—	—	275.0	—

* escapes from various ponds.

6.3 One of the objectives of the project was to devise technologies to enable local farmers to increase their culture productivity. The question that needs to be asked then is: do the production results indicate that such technologies have been developed? The answer is a *qualified yes.* With something as dependent on the environment and as site specific as aquaculture, a 3-year period with 6 culture operations is not really enough to say anything categorically. With differences in environmental parameters and variations in culture practice between ponds, comparison or aggregation is difficult. But what can be said is that while no single culture can be pointed to as being successful and representative in all respects, successes and improvements did occur often enough to suggest that the median numbers, if not the best numbers, are within the realm of technical possibility. The production figures for *P.monodon,* while low, are definitely more than what traditional production rates were at the start of the project and even more than present day rates, after local farmers have accepted technology from the project and elsewhere.

6.4 Macrobrachium: *M.rosenbergii* culture in the project's agro-aquaculture field had problems. The recovery rate was poor. In 1983 and 1984, 13,800 juveniles were released; 89 kg of the shrimp valued at Tk 8,268 was recovered. Only about 4-5 months from August were available for its culture; during this period, the shrimp grew to an average size of *30-50 g. Macrobrachium* of this size are not considered exportable and so fetched rather low prices. Culture of this species was therefore continued into the next year. Maintaining an appropriate water level for this species after October was a problem. The field had to be necessarily drained out by end-November for desilting the feeder canal and pond preparation. It was therefore necessary to transfer the shrimp to other ponds. The ponds contained water of higher salinity. During pond preparations in December-January, the shrimp had to be transferred again. Thus, the low water depths, higher salinity and frequent handling together affected shrimp survival and growth. However, the shrimp sexually matured and bred under the farm pond conditions as evidenced by the presence of gravid females and juveniles of the species in the ponds. Many of the shrimp harvested in 1985 were probably the offspring produced in the ponds in 1984.

6.5 Carp: Initial observations indicate that carp grew well in the AAF, but the recovery of the fish was very poor. Only 36 kg of carp was recovered in 1983. In 1985, about 108 kg of carp was harvested from a stocking of 12,000 carp fingerlings including silver carp. At stocking the salinity was 3-4 ppt. They grew to 200-500 g (av. 325 g) in about 3-4 months. The fish commanded low prices (Tk10-12/kg) in November-December because brackishwater fish supply was plentiful and kept the fish prices down.

6.6 Tilapia: From a population of 28,000 *Tilapia* fry of 15-25 mm size, stocked in ponds and the AAF during mid-August, 149 kg of the fish could be harvested. Harvesting was completed by end-November. Average size of the fish was 45-50 g. Recovery rate was very poor. One reason could be that unscientific seed transportation resulted in heavy mortality during transportation and immediately after release in the ponds.

6.7 Mullets: In 1985, a large number of mullet fry was stocked in various ponds, but the recovery from the ponds was unsatisfactory. Apart from the possibility of some loss due to escape, the fish probably suffered heavy initial mortality as in the case of Tilapia. Mullet fry collection and trading is not a regular practice in the area. On special contract, some local fishermen collected the fry and supplied them to the project. Having no experience in fish seed transportation, they brought the seed in heavily crowded conditions. The better production in the AAF could be due to natural stocking. Mullet growth in 1984 and 1985 was similarly low.

6.8 Paddy cultivation was attempted on the raised peripheral land on very limited scale in 1983 and produced good results. The production rate was comparable with what was normally achieved in the traditional farming systems in adjoining fields, not used for brackishwater aquafarming. In 1984, a special effort was made to cultivate paddy in a much larger area of the AAF which still contained a good population of fish and shrimp. About one hectare of *peripheral area, which contained shallow water while the seedlings were transplanted, produced 2 tonnes of paddy; this production rate compared quite favourably with the average-to-good production in fields in which brackishwater culture was not undertaken. The crop in another one hectare area in the AAF failed; this was apparently not due to the salinity but due to excessive water depth at the time of paddy transplantation. Although the water level was lowered before paddy transplantation, a certain minimum depth had to be maintained in the interest of the residual shrimp and fish population as well as the newly stocked carp and Macrobrachium populations. This depth was the bare minimum for the fish but proved detrimental to the newly transplanted paddy.

6.9 Production cost: The major inputs of production were seed, lime fertilizer and feed. A breakdown of production costs for 1985 is given below:

Production costs for 1985

(excluding investment and fixed costs)

(Tk)

	1985
Desiltation	46,676
Ploughing	1,212
Lime	15,432
Cowdung	3,432
Fertilizer	10,240
Seed	81,486
Miscellaneous supplies and harvesting	18,300
Total cost	198,325
Sale proceeds	304,780

6.10 Diseases: Softness in the shell and sponginess in the muscle of the shrimp was a common problem encountered in the first two years. The problem was attributed to nutritional deficiency, and was very widespread in 1984. A supplementary feed formulated with rice bran, fishmeal and calcium lactate improved the situation to a certain extent but could not completely cure the animals. Development of a whitish coating on the shrimp and crab shell, possibly due to a fungal infection, was also a common pathological problem encountered in 1983 and 1984. In 1985, the fungal infection cases could be detected in ponds 1, 7, 8 and 9 from September. An application of slaked lime 25 kg/pond (depth of water maintained at 75 cm) spread over a period of 5 days was found to gradually clear the infection of most of the animals; but the infection lingered on, and took its toll.

Diseased shrimp had stunted growth and a large number of them probably died as indicated by the low production figures. One interesting finding was that there was no incidence of fungal infection in the AAF. Further investigations would be needed to identify the factors that enabled disease resistance in the AAF.

7. TRAINING AND DEMONSTRATION

Study tours:

7.1 The Directorate of Fisheries of Bangladesh did not have manpower technically trained in brackishwater shrimp culture when the project wasinitiated. The project organized a field study programme to impart parctical training to the officers in basic techniques of coastal aquaculture. The tour programme was implemented in three instalments totalling four weeks. Golam Kibria, Team Leader and Habibur Rahman Khandker, Scientific Officer, took part in the study tours. They visited a number of private and public sector shrimp farms and a few coastal aquaculture research stations in West Bengal, India, during the first (13-18 September 1982) and second tours (25 Feb. — 4 March 1983). Dr. A.N. Ghosh, Shrimp Culture Consultant of BOBP, accompanied them. During the third trip (26 September — 9 October 1983), the officers visited the BOBP pen culture project in Killai, Tamil Nadu, and the pond culture project in Polekurru, Andhra Pradesh; besides these, they also visited some private shrimp farms and several coastal aquaculture experimental projects located in the two south Indian states and administered by various fisheries organizations.

7.2 The local engineering consultants appointed for detailed designing and construction supervision of the project farm did not have any previous experience in the design and construction requirements of brackishwater shrimp farms. It was felt that field studies of a few selected shrimp culture farms in West Bengal would give the two engineering consultants an opportunity to see the type of work they were required to do at Satkhira. The project therefore sponsored a 5day study tour (11-15 September 1982) for two engineers.

Local training

7.3 In response to requests from the Directorate of Fisheries of Bangladesh and as provided for in the project document, a practical training course was formulated. The 21day course was scheduled for implementation at the project site in three phases at different parts of the year in order to include all the basic aspects of a complete culture operation. The same group of trainees were required to participate in all the three phases to have a complete understanding of the shrimp-fish-paddy farming techniques. The training was designed for fisheries officers and educated farmers.

The three phases of the training were held 20-23 July, 8-18 December 1985 and 7-10 April 1986. The training course was inaugurated by the Minister of Agriculture, Forest, Fisheries and Livestock, Major General Mohammad Abdul Munim, and attended by the Director of Fisheries, the Deputy Commissioner, local elites and many shrimp farmers. The Minister stressed the need for practical training in improved shrimp culture techniques in Bangladesh and appreciated BOBP's pioneering efforts in this context. In all 19 trainees, 10 from the DOF, 3 from Caritas, Bangladesh, 1 from DANIDA, 1 from the Planning Commission of Bangladesh, and 4 educated private farmers participated in the course.

The first segment included training in water management, pest control and removal, agro-aquaculture, harvesting techniques, marketing and operational management. The subjects emphasized during the second segment included site selection, designing of brackishwater shrimp farms, identification of selected shrimp postlarvae, seed collection, segregation, transportation and marketing, pre-stocking pond preparations and nursery rearing practices in ponds and pens. The third and last segment took up feeding, feed preparation, general management and backyard hatcheries.

Detailed background papers relevant to each phase were prepared (Appendix 13) by the training instructors and made available to the trainees before the course began.

8. SCOPE FOR TRANSFER OF TECHNOLOGY AND ECONOMIC BENEFITS TO SMALL-SCALE FARMERS

The project became operational assuming what ways and means could be established to make the intensified shrimp culture methods accessible to small land owners around the project area.

As no information existed on the specific land ownership and land utilization pattern of the area around the project, a household survey was carried out by a Dhaka-based consultancy firm to identify small land owners. In addition to this survey, which covered all 2242 families in the 3.2 km area around the demonstration farm, information on employment patterns was obtained through intensive interviews and informal discussions with some 30 people during the course of the project implementation. It was revealed that about 60% of the semi-saline land was used for both shrimp and paddy cultivation whereas 40% was used to exclusively culture shrimp. The major part of the semi-saline and about 90% of the non-saline, high and dry land was found to be owned by less than 10% of the families. A little over 60% of all families were landless and nearly 30% owned very small plots of land, most of them not more than half an acre. Prior to the replacement of paddy-cum-extensive shrimp culture by semi-intensive shrimp culture, the small land owners and landless took land on lease either on a share cropping basis or against payment of a fixed land rent. The shrimp boom led to a number of small land owners leasing land to large farmers who, by over-flooding paddy fields, forced small owners to lease or sell their land. Consequently small farmers were found to be turning into landless labourers seeking employment in paddy and shrimp fields.

Before the advent of shrimp farming, only one aman crop was possible and off-season employment opportunities were limited. Studies by the Delta Development Project indicated that the introduction of shrimp culture within polders in the semisaline zone increased labour utilization when alternated with aman paddy farming. However, negative effects included reduction of grazing land, deterioration of drinking water inside polders and destruction of trees and bushes due to saline water intrusion. The economic benefits to the community seemed to be related to whether or not the shrimp farm operators were outsiders or members of local community, the effects tending to be negative in the former case because of the outflow of profits. In perennially flooded fields, employment opportunities are fewer than in paddy-cum-prawn culture. Fewer workers are employed on a year-round basis, except for pond construction and dyke repairs, when occasional labour is required. The wages paid for paddy and shrimp workers did not differ.

Unlike paddy cultivation, which offers at least some socially accepted employment opportunities for women of the area (threshing of paddy in the backyards), shrimp culture does not do so, as ail related work has to be carried out in public, something not accepted by the majority of families around the project area who are Muslim. Moreover shrimp culture tasks generally ascribed to women-like peeling, cleaning and packing of shrimp-are not carried out in the area but in nearby towns which are served by adequate roads. Only very poor women, without male income earners in their families, engage in shrimp processing along with their children. As shrimp processing during peak harvesting seasons is carried out until late at night, when society excepts women, to be at home, the women shrimp processors face ill-treatment by other women and harassment by men. Some shrimp peeling undertakings employ peelers in shifts, women and children in the day and men at night, in order to avoid disturbances in the work performance.

Given the land ownership, land utilization and employment situation in the project area, described above, plus the trend of small land owners losing control over their tiny plots of land (which are being taken over for shrimp cultivation by few large-scale farmers and absentee land owners), the project faced difficulties in its attempt to transfer improved shrimp culture technology to small-scale farmers. It also proved that shrimp culture, employing in particular the improved semi-intensive methods, was technically more feasible in a unit area larger than the land owned by small paddy farmers. However, since these small farmers lacked social organization and economic strength to form shrimp production cooperatives, and since their land plots were scattered, they either leased or sold their small paddy plots to resident and absentee farmers of adequate financial means and management skills to run the medium-to-large-scale shrimp farms. In some villages, farmers joined together for cooperative shrimp cultivation, but the management and control of profits rested entirely with a few strong shareholders who frequently prevented a correct distribution of profits among shareholders. This resulted either in breakdowns of cooperatives and non-utilization of land or in a continuation of the fake cooperative which benefited mainly the socially and economically powerful farmers who shared profits among themselves and only paid land rent occasionally to the small shareholders.

It was found that as a result of shrimp culture and its profitability, land rents had increased during recent years. Provided the powerful lessors paid the rents to the small owners, they at least received some income from their land. However, the income received from lease of land for shrimp culture proved to be lower than the net incomes of paddy farmers.

Net Earnings from 1 ha Land

1. Paddy culture (one annual crop): Tk. 11 700
2. Rent of land for shrimp culture : Tk. 7 450
3. Shrimp culture* : Tk 14 000 — 19 000

(* based on interviews with some 10 farmers around the project area. Net earnings are much higher in areas further south of the project with more favourable production conditions).

Paddy farming is being replaced increasingly by shrimp farming due to its higher profitability. Moreover, the ongoing process of canal siltation, preventing tidal water drainage from fields, has caused stagnation of water in the fields and salinity problems which prevent the utilization of the land for paddy culture. Consequently, the affected small paddy farmers had no choice other than leasing (or selling) their land to shrimp farmers; the latter could overcome the water drainage problem by investing in motor pumps to drain out water after a shrimp harvest, and pump in fresh water for the new shrimp crop. A shrimp farmer finds it viable to invest in a motor pump, a paddy farmer does not.

Similarly, as with agriculture (paddy and other crops), the profitability of shrimp culture does depend to a great extent on the ownership and control pattern of the land. It was found that large land owners with several hundred acres of shrimp land often achieved lower shrimp yields than medium land owners who looked intensively after the management themselves. Independent of the size of the holdings, very low productivity was reported from shrimp farms of absentee land owners (such as government employees) with other regular sources of income.

Consequently, an optimum increase in land productivity will not be achieved by demonstrating more intensive shrimp production techniques alone. The Government will also have to look into land ownership regulations if it intends to further promote increased shrimp production.

Medium-sized shrimp farms managed by the owners themselves would not only be the best option from the production and land utilization standpoints, but also from the employment point of view, since the production and management system applied is more thorough and intensive (dyke construction and maintenance, selective stocking, safeguarding etc.) than that found in absentee-owner farms.

9. EFFECTS OF THE DEMONSTRATION FARM

Shrimp farmers in the immediate area around the project and further south have picked up certain culture techniques demonstrated by the project. They are:

- Stocking (selective) of ponds at the rate advised by the project, 25,000 per ha.
- Pest removal before stocking (draining out of water) and while letting water into ponds through sluice gates during high tides (a screen has been fixed in front of the sluice to prevent the entry of predator fish and additional shrimps).
- Fertilizing with organic (cowdung + rice bran) and inorganic fertilizers.
- (In some rare cases) Nursery rearing, but with little additional feed.

The following demonstrated culture techniques were not adopted:

- Excavation of ponds.
- Farm lay out and feeder canals.
- Paddycum-shrimp culture (agro-aqua, field) (water and soil too saline to allow paddy to survive). Some private farmers have tried it without success.
- Nursing with sufficient additional feed (feed price too high, feed shortage problems).
- Fixed stocking and harvesting times. (Instead, private farmers practise gradual stocking and selective harvesting, and keep water in the ponds from Jan./Feb. to Nov./Dec. In this case, stocking occurs over extended periods, depending on farm size and seed availability.)

10. CONCLUSIONS AND RECOMMENDATIONS

Objectives: The project attempted to meet four objectives; two concerned with technical viability and technology development and two with technology transfer and the factors necessary for successful transfer. For various reasons the focus of the project tended towards the technical. However, the socioeconomic studies conducted and the informal meetings with local farmers did give the project an understanding of the technology transfer aspects of the culture practices that were evolved. The project seems to have had a positive impact on local farmers' productivity by introducing improved culture practices. One must qualify that statement with the fact that other influences could also have had an impact on local practices; therefore a clear causal relationship cannot really be drawn between uptake of technology and the project's efforts.

Production: Informal interviews with farmers and local fisheries officials before the establishment of the project suggested that the productivity of *P. monodon*, the most desired species, rarely went above 30-40 kg/ha, accounting for 15-20% of the total production. Similarly interviews after the project period suggest that the production had gone up to an average of 65 kg/ha and there are some instances of production of 100 kg/ha and above. There is no doubt that this increase in production is due to the farmers using culture practices like selective stocking, pest control, fertilization and manuring of ponds and some nursery management. What is difficult to prove is that the BOBP project was the sole reason for this improvement, since farmers of the region do have access to information from other sources.

In the project itself three years of culture practices were undertaken using various configurations of technologies. In something as dependent on the environment and as site specific as aquaculture, a 3-year period with 6 culture operations is not statistically significant enough for categorical conclusions. But while no single culture can be pointed to as being successful in all respects, the 1985 P. monodon production of 85-212 kg/ha, while low in absolute terms, is definitely more than what traditional farmers attained at the start of the project — or even after it, with all the technology inputs from the project and elsewhere.

One can conclude that with development and a judicious combination of recommended technologies it should be possible for the farmers to increase their production. However, it is necessary to point out some constraints to technology transfer, which highlight the need for further research and development Many of the technologies evolved in the project may not have a proportionate impact when directly applied to local farm conditions. This is because local farms are very large water bodies; pest control, water management, fertilization and manuring may not be as amenable to management as they are in the small (by comparison) project ponds. Further, the site specific nature of aquaculture would require a better farm-wise understanding of water quality and soil characteristics in order to tailor the inputs to local needs. All this would suggest further research and development particularly of the technology transfer mode that would customize broad technologies to specific local needs.

In absolute terms, while the project's 1985 production was significantly more than its efforts in the previous two years, the production per se was low, especially when all the inputs and the management are taken into consideration. The data does not allow us to pin down the reasons for the poor performance, but one can make some educated guesses: large-scale siltation of the rivers and canals of the region had greatly reduced the free exchange of water between the sea and estuarine system, and this has perhaps led to deterioration in water quality available for culture; the siltation, additionally, may have also reduced the natural productivity of the ponds by covering the benthic ecosystem and increasing water turbidity; the incidence of fungal infection in the shrimp population on a fairly regular basis could also indicate deteriorated water quality.

Management: Although liberal water exchange is generally recommended for brackishwater aquaculture, controlled water exchange may be desirable when the water is very silty and fertilization is intended. Heavy silt in the incoming high tide hinders effective photosynthesis in the pond, reduces the impact of pond fertilization and reduces pond productivity.

The rapid deposition of silt in the supply-cumdrainage canal also posed a big threat to the economic viability of the project. The desiltation process involved heavy annual recurring expenditure, upsetting the culture economics and drastically reducing the profit margin.

In order to ensure viable culture in the project ponds and in the large number of private shrimp farms in the neighbourhood, a comprehensive programme for desilting the Satkhira canal and Marichop river needs to be implemented urgently. Such a project will not only save the shrimp farms but also greatly revitalize the required waterways and facilitate drainage of the monsoon waters which waterlogs many polders. The project could be implemented jointly by the Zila Parishad and the Water Development Board.

In view of a general siltation problem in the upper parts of the Sunderbans deltaic region, any future brackishwater aquaculture efforts should be located near a more active and free-flowing river. However, such sites, which satisfactorily combine the environmental requirements and basic infrastructural facilities, are difficult to find along the brackishwater belt of Bangladesh.

Studies on the feasibility of using saline underground water for intensive shrimp culture could possibly solve some of the existing problems and produce useful information:

— With a good underground source of water, pond water levels during lean tide months (November-February) could be maintained.

— Pond salinity could be suitably adjusted for year round shrimp culture;

— Pest-free water for intensive nursery rearing and mono-culture of desired species could be rnade available; and

— Establishing a *Macrobrachium* hatchery if water of appropriate salinity is available, may become possible.

Pest Control: In a tide-fed pond, intrusion of a large number and variety of unwanted animals is a formidable problem. To reduce the magnitude of the problem, a great deal of attention is needed to perfect the groove construction in the sluice wall and floor. The pest control screen frame should fit as closely into the grooves as possible. A long conical screen of fine mesh (24 meshes per 2.5 cm length) was found to filter water more effectively than a straight screen of the same mesh size. The cone should be directed outwardly and tied to a pole fixed in the supply canal.

Since complete elimination of pests is not feasible, certain extra allowances for the intruder animals should be made while estimating the feed requirements for *P.monodon* stocked in a pond, in order to reduce the competition for food.

Continuous stocking and harvesting did not prove satisfactory. Harvesting the large shrimp without damaging the small ones was not always possible. Further, continuation of culture in the same tide-fed pond for a prolonged period inevitably led to heavy intrusion of the unwanted animals in the culture system. And the long periods allowed the pests to grow, increasing their negative impact.

Accepting the fact that intensive or semi-intensive culture operations in the project's tide-fed ponds would be very difficult due to the inevitable pest infestations, some changes in the culture techniques may well be worth trying. Culture operations in three stages, using various sets of ponds for relatively short periods in a cyclic order may produce better results. In this scheme, two sets of ponds (1st stage ponds) could be utilized, alternating with each other for nursery rearing (1st stage culture), ensuring that there is always an adequate nursery stock at least in one set of ponds for the next culture cycle. At the end of the first stage culture in a set of nursery ponds for about six weeks, the stock may be transferred to the second stage ponds prepared and kept ready in the meantime. The second stage culture may continue for two months, after which the stock may be transferred to the third stage or final stage ponds for rearing for another two months or until harvesting. At the end of each stage, the emptied ponds are dried to the extent possible and prepared afresh with lime, manure, etc. and restocked. This sort of management will keep the pest numbers and sizes to the minimum, remove or mineralize metabolites, release toxic gases at regular intervals and make the ponds fertile. However, it would also increase costs, and this needs to be balanced with the increased production due to reduced pests.

For example Pond 11 could be converted into two nursery ponds (1st stage); ponds 3, 6, and 9 into intermediate ponds (2nd stage); and ponds, 1, 2, 4, 5, 7, 8, 10 into final rearing ponds (final stage). In the AAF, culture in stages as stated above will not be possible without elaborate structural changes in the field; this may not be desirable if the original project concept is to be kept unaltered. However, it is important to keep in mind that any heavy investment on remodelling of the farm may be meaningful only if the associated rivers and canals can be adequately desilted.

Feed: Feed will be a crucial problem for intensive farming of shrimp, as it is for poultry and cattle farming. Government policy allowing bulk export of rice and wheat bran has reportedly led already to a shortage of these materials in the domestic market with a resultant price hike. Moreover, the quality of the locally available bran is very poor, with more of husk and little of the edible portion. Fishmeal availability is also limited, and its price is high and the quality fluctuates. Any substantial increase in the fishmeal supply is not foreseen, considering the country's insatiable need for food fish and that most of the known fish, inland or marine, is acceptable to Bangladeshis for direct consumption. In view of this situation, systematic experiments on manuring and fertilization as an indirect source of shrimp nutrition should be undertaken on a priority basis. At the same time the export of bran and similar materials could be reduced and diverted for local production of shrimp, fish, poultry and cattle.

Pathology: In-depth studies of the shrimp's pathological/physiological problems encountered in project ponds or in private ponds during last three years could not be undertaken. As a result, the project could not recommend precise prophylactic measures against some of the above problems including the white scum on shrimp and crab shells, disproportionate growth of appendages (reported by private farmers), and high incidence of soft shell. Further research on the above is needed.

Rice-cum-fish: In years of normal (or above normal) monsoonal rains, and the resultant low salinity conditions, paddy could be grown satisfactorily and compatibly with brackishwater species of fish and shrimp in the AAF project. It was observed that a field with a good slope or low areas offered better opportunities to combine aquaculture with paddy cultivation. In such fields the fish and shrimp could be temporarily concentrated in low-lying areas having adequate depths of water, exposing most of the field for paddy transplantation. Subjected to heavy siltation, the AAF's southern part, originally quite low in elevation, was substantially raised, rendering rice cultivation concurrently with fish in the field quite difficult, since appropriate depths for aquaculture could not be maintained. The AAF would require extensive trenching in order to keep the field fit for combining aquaculture with agriculture.

Other aquatic species: Macrobrachium rosenbergii, though a fresh-water shrimp, was found to survive the highest salinity recorded in the ponds (18 ppt). They also bred in the ponds from which juveniles of various sizes were collected. However, with the characteristic slow growth, the species took about 8-10 months to reach 100 g size, and shrimp below this size were not acceptable to shrimp processors in Bangladesh. Thus, polders with low-lying areas which can retain sufficient depth of water throughout the year can be conveniently utilized for Macrobrachium culture. Its culture in the project's AAF may not be worthwhile, since it is difficult to maintain adequate depth and water in the field beyond November.

Good growth rates of *Ctenopharyngodon idella* and *Catla catla,* juxtaposed with their poor survival in the AAF, suggest that:

- There exists a good possibility of culturing freshwater carp in brackishwater farms during low-saline months;
- Carp fingerling stocks of freshwater origin very likely suffered heavy initial mortality when directly stocked in saline water of 3-5 ppt and above; this warrants acclimatizing the fingerlings to a saline environment in stages. Acclimatization of a large number of fish would require extensive and expensive facilities, which may not be worthwhile, particularly since the price of carp in the local market during November-December is very low and the environmental salinity may not be congenial for carp culture every year;
- It may not be wise to include carp species in the regular culture programme since its culture may be economically attractive only in years of early and heavy rainfall, lowering the salinity sufficiently (below 3 ppt) for at least four months from July.

Seed: The strong trend towards selective stocking and increased stocking density in private farms has resulted in a very high demand for P. monodon seed. Seed collection efforts have increased substantiaily, but seed demand remains unfulfilled. There is a view that seed may soon limit further expansion or intensification of the culture operations. The seed price has gone up remarkably during the last few years. Although hatcheries could be alternative or supplementary sources of the P. monodon seed, suitable sites for establishing shrimp hatcheries would be very difficult if not impossible to find in this region, where salinity is rarely high enough to establish penaied hatcheries. The situation thus calls for an urgent survey of P. monodon seed availability in the Sunderbans estuarine areas. If the survey yields promising results, appropriate measures will have to be taken to gather, transport and distribute the seed, as far as practicable, through the small-scale sector. Seed collectors collect only P. monodon post larvae and throw away all the other shrimp and fish seed which have a huge production potential. Preliminary studies suggest that if monodon seed makes up less than one-hundredth of the total collection, and that currently about 1 billion P. monodon seed is collected every year in the Khulna region. On this basis 99 billions of postlarvae and young ones of other shrimp and fin fish are removed from the production cycle. This situation warrants an immediate study to assess the actual quantum of damage of shrimp and fish resources and adoption of practical measures to stop or at least reduce the loss of the fishery resources.

Socio-economics of technology transfer to small farmers:

- Since hardly any small shrimp farmers existed, the new intensified shrimp culture methods could not be transferred to this group of people. Instead, training courses were conducted for medium and large shrimp farmers.
- The prevailing politico-economic power structure does not encourage small farmers to form shrimp production cooperatives which would be a basis for access to new intensified shrimp culture methods.
- Small land owners can therefore benefit from the new intensified methods demonstrated by the project only as employees in large shrimp farms.
- From those who are fortunate enough to find employment, the family's income situation is not likely to deteriorate, since they are generally employed year-round and not only seasonally. However the problems of people who have not found any employment after losing their own land have to be solved by means of different approaches. It is to be borne in mind that an approach to solve the income problems of small land owners and prevent the ongoing process of turning them into unemployed landless people, can only be successful if backed by adequate Government strategies.