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Carp Production in Seasonal Water Bodies in Eastern India

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Abstract

The feasibility of integrated aquaculture in seasonal water bodies in rainfed farming areas of Eastern India was assessed in on-farm trials. Fry of Indian major carps (IMC: *Catla catla*, *Cirrhinus mrigala*, *Labeo rohita*), common carp (*Cyprinus carpio*), and silver barb (*Puntius gonionotus*), and advanced fingerlings of IMC were raised to marketable size. Mean survival of fish varied, with silver barb showing a significantly higher survival rate ($P<0.05$) than IMC and common carp grown from fry. Silver barb grew to significantly smaller sizes ($P<0.05$) than common carps and IMC grown from advanced fingerlings. Capital costs ranged from Rs2400 to 10,500 ($56 to 244), and variable costs from Rs2850 to 8950 ($66 to 208) per cycle. The species of fish and their size at stocking were important for ensuring success; common carp and silver barb can grow fast enough to reach market size in a seasonal pond, whereas IMCs should be stocked at 14 to 16 cm length if expected to grow to market size during the wet season.

The key factors for the success of aquaculture in seasonal water bodies were access to credit, production enhancing inputs and water bodies that hold water for more than 120 days in a year. The availability of low cost labor and the current livelihood strategy of the farmers were also important.

Introduction

The Indian Department of Fisheries (DoF) has long promoted aquaculture as a livelihood alternative for poor farmers. At present all aquaculture research and extension in the country focus on relatively resource-intensive polyculture systems in perennial water bodies, with high stocking densities and extensive reliance on relatively expensive off-farm inputs. However, the majority of the country's poor live in rainfed areas, with no access to year-round water resources and limited funds available for investment into fish culture. They are small-scale farmers, cultivating rice and a few vegetables, many have limited access to water for irrigation and only few livestock. Most of them belong to the scheduled castes or tribes, and in contrast to the higher castes, who are mainly vegetarian, fish form an important part of the diet for these communities. For aquaculture to contribute to poverty alleviation among these marginal communities, integrated approaches that suit and enhance their current livelihood strategies need to be explored. Recommendations suitable to farmers' conditions and resources, based on their needs and livelihood objectives, should be developed.

The East India Integrated Aquaculture project, of which this research is a part, aims to select, test and develop integrated aquaculture innovations relevant to local needs and conditions. The project area covers parts of Bihar (now Jharkand state), West Bengal and Orissa. The majority of farmers grow paddy, commonly only one crop a year because of limited irrigation facilities. Most water bodies in the area are seasonal, and some of these are suitable for aquaculture activities, as are a number of perennial ponds.

The project is process oriented, farmers decide the activities undertaken as the project proceeds. Farmer research support committees such as the Matsya Anusandhan Sahayak (MAS) Committee, identify research needs and plan on-farm trials. The role of the MAS Committee is to plan, manage and report farmer research, to identify need for and request outside support, and to host village-based open days. Members include farmers' groups, the chair of farmers' groups, community organizers from the Indo-British Rainfed Farming Project (IBRFP), and aquaculture research team members.

At the start of the project, groups of resource poor farmers in remote parts of West Bengal, with access only to temporary water bodies, reported important constraints to the introduction of aquaculture into their livelihood systems. One limiting constraint was the lack of information on the use of seasonal water bodies for fish production. The use of temporary water bodies for aquaculture was restricted by the poor availability of larger fingerlings or fast-growing species of fish, which can grow to a marketable size during water availability. Farmers also reported a general lack of information on how to raise fish to marketable size using the inputs available to them. In response to farmers' demand, the project investigated a number of options for producing fish in short season water bodies. This paper reports the local production of market-sized fish in seasonal water bodies by farmers' groups from fry of Indian major carps (catla: *Catla catla*, mrigal: *Cirrhinus mrigala* and rohu: *Labeo rohita*), common carp (*Cyprinus carpio*), and silver barb (*Puntius gonionotus*), and from advanced fingerlings of Indian major carps. Other parts of the project have investigated the early (prior to the onset of the rains) staged production of fry and advanced fingerlings in water from perennial ponds for grow-out in seasonal ponds.

Materials and Methods

Seventeen trials growing fish from fry or advanced fingerlings to table size were conducted by farmers' groups in clusters of villages associated with the East India Integrated Aquaculture project and the IBRFP. The geographical location of the villages is shown in figures 1 and 2. Table 1 is a summary of the farmers' groups involved, and table 2 outlines the ponds and experiments.

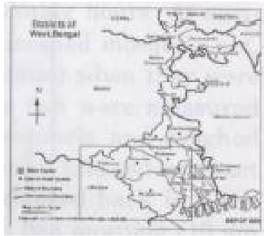

Fig. 1. District in West Bengal, India

MAS Committee meetings were carried out in the spring of 1998, and groups who chose to do aquaculture trials were trained in aquaculture practices by the project staff of the Central Institute of Freshwater Aquaculture (CIFA) and the Society for Rural Industrialisation, an Indian national NGO, providing among other things, aquaculture training for interested parties. After the training, farmers' groups selected their own stocking densities and levels of production enhancing inputs.

Fig. 2. The location of research clusters in West Bengal

Seasonal ponds were stocked after the first rains in June to August and fish were harvested when water levels became low (September to March, depending on pond location and characteristics). The farmers and project staff agreed on the date of the harvest based on water level and farmer availability (for harvesting, sampling fish and recording data).

Lime was applied to the ponds 16 days before stocking. Five days later, cow manure was applied by mixing it with water into a very thick solution and sprinkling it by hand onto the water surface of the ponds. Six days after manuring, Single Super Phosphate (SSP) and urea were added to pond water at a ratio of 2:1, by mixing it with small amounts of manure and leaving it for one night before sprinkling the mixture onto the pond surface.

Advanced fingerlings (trials 10 to 17) were treated with 250 to 500g potassium permanganate (amount depending on the number of fingerlings stocked), added to the transport container and then mixed gently with the pond water just prior to stocking the fish. Potassium permanganate was also added to the ponds when the farmers noticed that the fish were stressed or suffering from disease.

Fry of 30 mm total length (0.6 g) were acquired at local fry centers (maximum transport time 2 hours) by the project on behalf of farmers' groups. In five ponds, advanced fingerlings of about 150 mm were stocked. In trials 1 to 9, 16 and 17 fish were transported to the site in oxygenated water in plastic bags, whereas in trials 10 to 15 fingerlings were transported in non-aerated local fry-transport containers (*hundies*) by bus to the sites. Fish were stocked after conditioning following the recommendations of Haylor and Muir (1998). The number and size of fry or fingerlings stocked were recorded at the time of stocking. After stocking, a supplementary feed of rice bran and mustard oil cake (1:1 by weight) was administered daily.

Table 1. Details of groups.

Name of group	Members	Village, cluster	Social status	Caste	Activities other than aquaculture
Bamu Mahila Samiti	20 F	Bamu, Kaipara	All D	All GC	Crops, pump
Khawasdih Mahila Samiti	25 F	Khawasdih, Kaipara	All D	All GC	Crops, goats, SWC, pump
Khamartarn Navatarun Sangh	24 M	Kaipara, Kaipara	21 D; 2 SS; 1 S	12 ST; 3 SC, 9 GC	SWC, nursery, crop, thrasher
Kaipara Nabayub Sangh	58 M	Kaipara, Kaipara	54 D; 2 SS; 2 S	18 SC, 40 GC	Bamboo craft, nursery, crop, thrasher
Nabodaya	7 M	Jabarrah, Jabarrah	5 D; 1 SS; 1 S	All GC	Crops, pump
Ma Santoshi	10 F	Jabarrah, Jabarrah	9 D; 1 SS	All GC	Sheep, crops
Kasidih Adiwasi Jankalyan Samiti	11 M	Kasidih, Jugidih Kasidih	6 D; 2 SS; 3 S	All ST	Agriculture, SWC, plantation, lac culture
Halisirjin Jumit Gonta	5 M; 5 F	Parulia, Medni	8 D; 2 SS	All ST	Agriculture, SWC, crop, agroforestry
Avenkuheli	5 M; 5 F	Kharkabad, Medni	All D	2 ST, 8 GC	Crop, agroforestry
Jal	4 M; 1 F	Ghotidoba, Pasro	All D	All ST	Agriculture
Padalochan	9 M	Jabarrah, Jabarrah	7 D; 1 SS; 1 S	All GC	Crops, pump

M: Male; F: Female; GC: General caste – all non-Scheduled Castes (SCs), Scheduled Tribes (STs) or other backward castes as designated by the Indian government. SCs: lower castes identified by the Indian government as a means of classifying castes for the allocation of benefits. STs: all tribals. SCs and STs together constitute the 'socially and educationally backward classes of citizens'. The terms form the basis for policies of protection and positive discrimination. Project farmers are divided into surplus, self-sufficient and deficit wealth groups: S = Surplus farmers produce more food grain than they need, sell surplus to generate extra income. Own better quality land (medium and lowland), and can afford a variety of food in their daily diet (including meat). Often provide secondary employment and nutrition to lower wealth groups. SS = Self-sufficient villagers have adequate land to produce sufficient food for their family. Approach two square meals per day and can afford meat occasionally. May take occasional loans at times of emergency. D = Deficit villagers are the most disadvantaged group. Often struggle for two square meals a day. Staple diet is rice, with only occasional additions of meat and vegetables. Generally own small plots of land in upland areas (poor quality soil). Few alternative sources of income and commonly work as wage labourers at most times. 70-80% of deficit farmers access non-institutional credit at high interest rates. SWC: Soil and Water Conservation; lac culture: the culture of Ber (*Zizyphus jujuba*) and Kusum (*Scheleichera oleosa*), inhabited by an insect, which produces lac, used for the manufacture of bangles, sealing materials, polish and varnish.

Each pond was sampled 4 to 5 times during the growth period. Sampling was carried out in the early morning or late evening hours. At sampling times, all fish were caught using either a fine meshed mosquito net, when the fish were small, or a drag net (mesh size 15 mm) when they were larger. A randomly selected subsample of 20% of the fish were measured from the tip of the mouth to the tip of the caudal peduncle and weighed (using a Salter EK 1200 g, A&D Instruments Company Limited compact digital balance, d=0.1 g) and the remainder were released back into the pond. Water quality parameters were measured in the late morning (10 am to noon) on sampling days, using a HACH Fish farming test kit, model FF 1A, Cat. no. 2430 – 02.

Based on information provided in the aquaculture training, farmers decided on and kept records of the amount of supplementary feed and organic manure used in the trials. Manure was administered from locally manufactured bamboo baskets and the amount added was estimated based on the knowledge that one basket contains about 25 kg of cow manure (G. Dutta, IBRFP (East) Aquaculture Specialist, pers. com.).

Costs of all local materials and services used for the financial analysis were obtained from farmers and from a number of sources, including the District Fisheries Officers of the Department of Fisheries, IBRFP staff, and market surveys. After the trials, all of the farmers' groups participated in a 'network meeting' to share the research results. The work required for all activities associated with market size fish rearing was discussed during the meeting, and used in the current analysis. The statistical software Minitab was used for data analysis.

Table 2. Details of trials. SB: Silver barb (*Puntius gonionotus*), CC: common carp (*Cyprinus carpio*), IMC: Indian major carps: catla (*Catla catla*), mrigal (*Cirrhinus mrigala*), rohu (*Labeo rohita*).

Trial no.	Group(s) involved	Species	Size of pond (ha)	Avg. length at stocking (mm)	Stocking density (no/ha)	Growth period (days)	Comments
1	Padalochan	SB	0.405	30	12,350	91	
2	Bamu M. Samiti	SB	0.607	30	11,527	126	
2	Khawasdih M. Samiti	SB	0.405	30	12,350	177	
4	Khamartarn N. Sangh	SB	0.526	30	7,600	173	
5	Khamartarn N. Sangh	SB	0.324	30	15,438	158	
6	Bamu M. Samiti	CC	0.405	30	12,350	184	
7	Kaipara N. Sangh	CC	0.405	30	14,820	162	Skin lesions on fish
8	Nabodaya & Ma Santoshi	CC	0.405	30	12,350	188	Skin lesions on fish
9	Kasidih A. J. Samiti	CC	0.081	30	37,050	198	
10	Khawasdih M. Samiti	IMC	0.162	153	18,525	153	
11	Halisirjin J. Gonta	IMC	0.405	145	8,645	193	Pond dried out
12	Avenkuheli	IMC	0.243	143	8,233	192	Pond dried out
13	Jal	IMC	0.101	155	9,880	213	
14	Nabodaya	IMC	0.405	25	12,350	205	Disease
15	Padalochan	IMC	0.405	25	17,290	206	Disease
16	Kaipara N. Sangh	IMC	0.324	30	9,263	107	Disease. No water quality data.
17	Kaipara N. Sangh	IMC	0.324	30	10,806	107	No water quality data.

Results

The survival rate of the different species grown to marketable size can be seen in figure 3, and the mean size of the fish at harvest in figure 4. Analysis of variance (ANOVA) showed the mean survival rates of the four trials to be significantly different ($P<0.001$). The mean survival rate of IMC stocked as fry ($P<0.05$) was significantly lower than the survival obtained for IMC stocked as advanced fingerlings. In fact, IMC stocked as advanced fingerlings showed a mean survival rate of 50%, 30% higher than IMC stocked as fry. At about 60%, the survival rate of silver barb was significantly ($P<0.05$) higher than all the other species stocked as fry. However silver barb grew to a significantly smaller size ($P<0.05$) than common carps and IMC grown from advanced fingerlings. There was no significant difference between the size of fish at harvest of IMC grown from fry and silver barb.

Because of the different lengths of the trials and the different sizes of fish stocked, the mean specific growth rates (SGRs) may be a better indication of actual growth than the size at harvest. These are shown in figure 5. Common carp, IMC reared from fry, and silver barb all had significantly higher SGRs ($P<0.05$) than IMC reared from advanced fingerlings. No relationship was found between survival rate, SGR, and weight at harvest, and stocking density, or feed and fertilizer inputs. As water quality parameters remained well within the tolerance limits of all species (Table 3), these are unlikely to have affected the growth rates or survival of the fish.

The amount of inputs that farmers decided to use varied between the trials, and table 4 shows the maximum, minimum and average use of feed and organic and inorganic fertilizers. Table 5 shows the growth and survival of the fish and the financial analysis of the trials. Capital costs for rearing marketable sized fish are in the range Rs2400 to 10,500 ($56 to 244), depending on the number of fish stocked (hence the approximate size of the pond). Variable

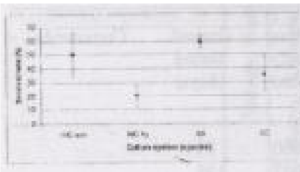

Fig. 3. Survival rate, and 95% confidence intervals, of the different culture systems tested in Eastern India. IMC adv: Indian Major Carps grown from advanced fingerlings to table size, N= 4 trials; IMC fry: Indian Major Carps grown from fry to table size, N = 4 trials; SB: silver barb, *Puntius gonionotus*, grown from fry to table size, N = 5 trials; CC: Common Carp, *Cyprinus carpio*, N = 4 trials. Silver barb and common carp grown from fry to table size.

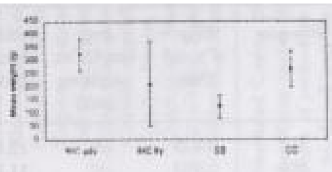

Fig. 4. The mean weight at harvest, and 95% confidence intervals, for the different culture systems of the trials. IMC adv: Indian Major Carps grown from advanced fingerlings to table size, N = 4 trials; IMC fry: Indian Major Carps grown from fry to table size, N = 4 trials; SB: silver barb, *Puntius gonionotus*, grown from fry to table size, N = 5 trials; CC: Common Carp, *Cyprinus carpio*, N = 4 trials. Silver barb and common carp grown from fry to table size.

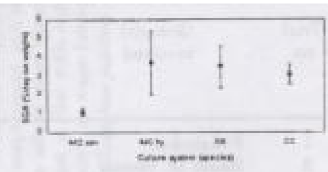

Fig. 5. Mean specific growth rates (SGR) and 95% confidence intervals. IMC adv: Indian Major Carps grown from advanced fingerlings to table size, N = 4 trials; IMC fry: Indian Major Carps grown from fry to table size, N = 4 trials; SB: silver barb, *Puntius gonionotus*, grown from fry to table size, N = 5 trials; CC: Common Carp, *Cyprinus carpio*, N = 4 trials.Silver barb and common carp grown from fry to table size.

costs ranged from Rs2850 to 8950 ($66 to 208 per cycle). Production enhancing inputs (feed and fertilizer) constituted the largest proportion (26 to 59%) of the variable costs, whereas fish seed represented 12 to 48%. In the financial analysis the local cost of manure was used, however in all the trials, individual group members supplied the manure from their own livestock. The amount of manure used in the trials varied between 12 to 87 kg ha^{-1} day^{-1}, the average was 35 kg (std. dev. 20). Seed costs as a proportion of the total variable costs were highest for silver barb and common carp, followed by IMC advanced fingerlings and lastly IMC fry.

The ownership patterns of ponds in the area vary. About 70% of the groups who owned their ponds, belonged to two categories. In groups based on kinship, related families form a group and manage the family pond. In villages, which were allocated a water body as a common property resource from the local block development office, all households from the village were members of the group and managed the pond by elected committees. The remaining 30% of ponds were owned by individual group members, who allowed aquaculture sharecropping. Most of the groups who took part in the trials owned their ponds, only one of these (Kaipara Nabayub Sangh, trials 16 and 17) was a common property resource which belonged to the whole village. However, in a sharecropping system 20 to 50% of the harvest belongs to the pond owner (G.

Table 3. Key water quality parameters of the experiments. Water quality measured every time fish sampled, measurements taken late morning. All ponds were sampled between 4 to 5 times. No water quality data is available from experiments 16 and 17. Depending upon the climate the pH increased by 1 to 3 units from morning to afternoon and temperature by 2 to 4°C or more.

Trial	Minimum Temperature °C	Maximum Temperature °C	Minimum Plankton Density (ml $100l^{-1}$)	Maximum Plankton Density (ml $100l^{-1}$)	Minimum pH	Maximum pH
1	24	27	1.3	1.8	7.5	8.5
2	20	26	1.0	1.8	7	8.5
3	23	25	0.4	2.0	7	8
4	22	26	0.5	1.5	7	7.7
5	21	28	1.0	1.8	7	8.5
6	21	23	1.0	1.5	7	7.5
7	20	25	1.0	2.0	7.5	8
8	20	26	1.0	2.2	7	8
9	23	27	1.5	2.5	7.5	8.5
10	20	25	1.0	1.7	8	8.5
11	22	25	1.5	1.8	8	8.5
12	22	24	0.8	2.0	7.5	8.5
13	20	25	1.0	2.0	7.5	8
14	22	26	1.0	2.0	7.5	8
15	20	26	1.0	1.8	7.5	8

Table 4. The level of inputs (kg ha^{-1}) to aquaculture ponds

	Maximum	Minimum	Average	Standard deviation
Cow manure	17,284	2264	5752	3790
Inorganic fertilisers	975	206	401	217
Mustard oil cake	1296	185	546	252
Rice bran	1296	185	558	272

Table 5. Financial analysis of table size fish production. All prices are in Indian Rupees. SB: Silver barb (*Puntius gonionotus*), CC: common carp (*Cyprinus carpio*), IMC: Indian major carps: catla (*Catla catla*), mrigal (*Cirrhinus mrigala*), rohu (*Labeo rohita*).

Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Species	SB	SB	SB	SB	SB	CC	CC	CC	CC	IMC	IMC	IMC	IMC	IMC	IMC	IMC	IMC
Length of trial (days)	91	126	177	173	158	184	162	188	198	153	193	192	213	205	206	107	107
No of fry stocked	5000	7000	5000	4000	5000	5000	6000	5000	3000	3000	3500	2000	1000	5000	7000	3000	3500
Avg. wt. of fish harvested (g)	76	174	131	126	125	307	275	285	207	314	301	302	380	344	246	137	130
Selling price per kg (Rs)	30	30	30	30	30	25	25	25	25	40	40	40	40	40	40	40	40
Total income (Rs)	6,995	19,606	11,594	9,450	11,700	12,280	13,599	10,688	7,286	14,884	18,325	14,064	9,160	9,384	17,640	3,400	3,640
Stocking density (no/ha)	12,350	11,527	12,350	7,600	15,438	12,350	14,820	12,350	37,050	18,525	8,645	8,233	9,880	12,350	17,290	9,263	10,806
Survival rate (%)	61	54	59	63	62	32	33	30	47	40	43	59	59	14	26	21	20
SGR (% day^{-1} on weight)	4.76	4.09	2.75	2.80	3.06	3.11	3.47	3.01	2.69	1.25	1.09	1.02	0.97	2.85	2.67	4.60	4.55
Capital costs																	
Pond rental** (Rs)	3498	9803	5797	4725	5850	6140	6799	5344	3643	7442	9162	7032	4580	4692	8820	1700	1820
Nets, buckets, etc. (Rs)	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700	700
Total capital costs (Rs)	4198	10,503	6497	5425	6550	6840	7499	6044	4343	8142	9862	7732	5280	5392	9520	2400	2520
Variable costs																	
Fish seed (Rs)	2375	3325	2375	1900	2375	2375	2850	2375	1425	1500	1750	1000	500	750	1050	450	525
Feed (Rs)	855	2850	2185	1900	2138	2375	2470	2612.5	998	1064	2211	1140	570	1503	2188	570	769
Fertiliser (Rs)	438	833	966	824	834	940	890	952	490	871	615	278	570	1353	3095	465	598
Lime (Rs)	650	910	975	650	910	975	975	910	553	650	780	410	221	1170	1625	390	546
$KMNO_4$ (Rs)										475	475	475	475	380	380	380	380
Transport of seed and inputs (Rs)	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Total variable costs (Rs)	4918	8518	7101	5874	6856	7265	7785	7450	4065	5160	6431	3903	2936	5755	8938	2855	3418
Gross margin*** (Rs)	2078	11089	4493	3576	4844	5015	5814	3238	3221	9724	11894	10162	6224	3629	8703	545	223
Opportunity cost of labour (Rs)	2198	3513	1395	2625	1943	2271	481	645	627	8051	2051	1394	984	5575	4378	1450	1668
Gross margin - labour costs (Rs)	-120	7576	3098	951	2902	2744	5333	2593	2595	1672	9843	8768	5240	-1946	4325	-905	-1445
Payback period (cycles)		1.4	2.1	5.7	2.3	2.5	1.4	2.3	1.7	4.9	1.0	0.9	1.0		2.2		

* Varies with time of year in seasonal water bodies.
** Taken to be half the income (worst case scenario according to G. Dutta, IBRFP(East) Aquaculture Specialist, pers. com.).
*** Total income - variable costs

Dutta IBRFP, pers. com.). To assess the viability of aquaculture for nonpond owners, it was assumed in the financial analysis that farmers had to pay a share of the harvest to the pond owner, and at the worst 50% was used. Using this estimate, pond 'rental' comprised 71 to 93% of capital costs.

The important components of labor inputs are pond preparation, feeding and security (Fig. 6). In areas where theft is a major problem (e.g. Northern Purulia, trials 1 to 8, 10 and 14 to 17) the total labor cost accounted for up to 83% of gross margin if pond guarding was computed based on the local labor rate. However most groups did not have to spend for the guarding of the pond, as a young male group member could sleep near the pond.

Unfortunately, four of the trials were unprofitable. Three of these were the trials involving IMC grown from fry. The unprofitability of the trials could be attributed to the low survival of the IMC grown from fry (14, 16 and 17), and the short duration of three of the trials (1, 16 and 17) where the drying out of the pond forced farmers to harvest prematurely. A sensitivity analysis shows that if the groups do not have to pay for guarding the pond, all the trials except numbers 16 and 17 were profitable. The rate of pond rental had a significant effect on the payback rate. Figure 7 shows the effect of lowering the pond rental on the payback cycles for a number of trials, including those with the highest present payback period (trials 4 and 10). As can be seen, at a pond rental rate of 20% of the harvest, even the least profitable trials could pay back the initial investments within three aquaculture cycles.

To allow comparison of the returns from aquaculture with those of agriculture of an area similar to the ponds, table 6 shows the profits obtained by farmers in the project area from typical agricultural activity. Due to the dry

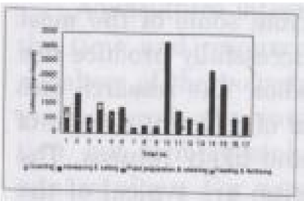

Fig. 6. Different categories of work associated with the aquaculture trials.

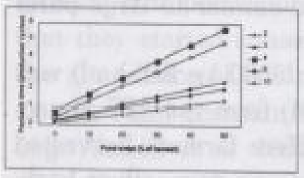

Fig. 7. The effect of the rate of pond rental on the payback period for some of the trials (trials 2, 3, 4, 6, and 10, for details of the trials see Table 4).

Table 6. Gross income and net profit from agriculture of typical crops for the area, obtained by farmers in the project region.

Crop	Typical production (kg $acre^{-1}$)	Gross income (Rs $acre^{-1}$)	Gross margin (Rs $acre^{-1}$)
Irrigated high yielding rice	1600	5800	1450
Dryland local rice	530	1815	454
Irrigated tomato	2200	660	2640
Irrigated aubergine	3000	6000	1800
Irrigated cabbage	7500	10000	5000
Irrigated cauliflower	3000	8500	4250

nature of the environment, the most profitable crops were those requiring irrigation, for which the farmers either had to own a pond or gain access to a common property water resource.

The feedback from farmers on the trials was generally positive. Groups growing silver barb and common carp commented on how fast these grew compared to IMC. In some ponds the farmers reported a disease where black spots appeared all over the body of some of the fish. According to farmers this disease only affected IMC, not the common carp or silver barb. During the Farmers Network Meetings, all groups stated that they intended to grow fish again without support from the project. At the time of writing this report, a survey was conducted following up the level of retention of aquaculture without support from the project, and its impact on local livelihood.

Discussion and Conclusion

Ownership and access rights determine the potential use of water resources. Most perennial water bodies involve a number of stakeholders, with owners ranging from government, community, kin groups and individual households. Aquaculture in small seasonal ponds owned by individuals or kinship groups is less likely to lead to user conflicts. Previously, seasonal ponds were not used for aquaculture in the project area because no information was available on fast-growing species or larger seed, which could grow to a marketable size in a short time span. Although some farmers experimented with extensive culture of indigenous *Puntius* in their ponds, no results from these trials were available.

The present study demonstrated that farmers from some of the most disadvantaged socio-economic groups in India could successfully produce fish of marketable size in remote, rural, seasonal water bodies. The research also provided information on the likely growth and survival of different species of fish, capital and operating costs, labor requirements and likely returns. The states of Bihar, West Bengal and Orissa (research site) are typical of the rainfed farming systems throughout eastern India and similar to large parts of the semi-arid tropics.

The productivity obtained in the research (260 to 3600 kg $fish \cdot ha^{-1}$) was comparable to figures reported by Edwards et al. (1991) from the AIT Aquaculture Outreach Programme in Northeast Thailand. Here farmers harvested 530 to 2392 $kg \cdot ha^{-1}$ pond area from polyculture of common carp, silver barb, IMCs and Chinese carps. The size of Outreach ponds ranged from 400 to 500 m^2 and fish were stocked at similar to higher densities (1.2 to 2.4 fish m^{-2}) as in Eastern India. In an ICLARM – Government of Bangladesh collaborative project aiming to assess the socio-economic impact of fish culture extension programmes on the farming systems of Bangladesh, Ahmed et al. (1993) describes the integrated aquaculture practices in seasonal and perennial ponds. At comparable stocking densities to those used in India (0.8 to 1.7 $fish \cdot m^{-2}$), farmers in Bangladesh obtained generally lower production levels (200 to 900 kg $fish \cdot ha^{-1}$). However in Bangladesh, the level of production enhancing inputs added were low at 700 to 1200 kg cow manure·ha^{-1} compared to 2200 to 17,200 kg, and 1 to 30 kg oil cake·ha^{-1} compared to 185 to 1300 kg·ha^{-1} in India. Gupta et al. (1999) described ICLARM's experiments in Bangladesh in seasonal water bodies with monoculture of silver barb and Nile tilapia, and polyculture of these species with other carps. In the ICLARM project, farmers used slightly higher stocking densities (average 1.6 fingerlings·m^{-2}) and with more than three times as much manure and feed per unit pond area after 7 months harvested 1000 to 3000 kg fish per ha pond area. One of the findings of the ICLARM project was that only wealthier farmers adopted aquaculture, and the relatively high level of inputs used in the project may be a reflection of the higher levels of resources available to participating farmers in the Bangladesh study.

Due to their relatively slow growth rate, IMCs have previously been reported to perform badly in seasonal water bodies (Morrice 1998). In E. India, similar to that in Thailand (Little et al. 1991), IMC survival rate was low if the fish were stocked as fry and much higher if stocked as advanced fingerlings. The good growth and high survival rates of silver barb have previously been reported (Little and Pornvanit 1995) but their relatively small size means that production levels remain low for this species.

Aquaculture has the potential to diversify the livelihood of the farmers. However, the space taken up for the use of a pond could be used for agricultural production. Owing to the dry nature of the region, if farmers can afford a pump and have access to electricity, most of them will use seasonal ponds for small-scale irrigation of vegetable plots. Stocking fish into the pond may provide a complementary use of the water, from which profit can be gained from a small initial investment.

Aquaculture integrated into the existing farming system will affect both the time and resources allocated to other farming activities by different members of the household. A financial analysis of the viability of incorporating fish production into the farm portfolio provides useful guideline information, but farmers make decisions based on a number of factors, not on finances alone. For example in Northeast Thailand, more than 40% of the farmers who participated in the Aquaculture Outreach Programme reported that they started aquaculture because they wanted fish to eat, many because the abundance of wild fish were declining (Demaine et al. 1999).

In rural communities in Eastern India, as in many other parts of Asia (e.g. Ahmed et al. 1993; Demaine et al. 1999) it is common practice to eat meat during religious ceremonies, weddings, or offer them as presents to friends and relatives. Fish provides a relatively low-cost alternative to chicken or goat, and as such may contribute positively to the social networking of a family. Fish provides a valuable protein source rich in essential fatty acids, and if used for home consumption, fish from aquaculture in seasonal water bodies could significantly improve family nutrition. Aquaculture as an added livelihood activity may diversify the farmer's portfolio, thus spreading risk and increasing options.

Fish culture is not very labor intensive, but if the pond is located far from the homestead, protecting it against theft may require somebody to sleep nearby. In Bangladesh, richer farmers who adopted aquaculture in seasonal water bodies used both their own and hired labor, but on the average, fish culture activity only required 12 person days per year because the ponds were not guarded at night (Gupta et al. 1999). In the AIT Outreach Programme in Northeast Thailand, a follow-up survey documented that 90% of fish farmers guarded their ponds to some degree, mainly during the day rather than at night. However as most of the ponds in the area were located within the homestead, guarding did not cause an extra burden (Demaine et al. 1999). At the time of pond preparation and harvest, aquaculture activities are both time consuming and strenuous. Seasonal migration for work is common in many parts of rural India, and the availability of adults for harvesting the fish needs to be considered. Due to cultural factors constraining the activities of women in India, only men can dig ponds, guard them and harvest the fish (Felsing 1998; Gopalakrishnan 1996; Mohanty and Jena 1996). However, women often feed the fish and are involved in processing and marketing activities. Men are commonly in charge of the finances, and major decision-makers in terms of investments. The introduction of fish culture may give rise to uneven distribution of workload and benefits for different family members, and the potential impact of the introduction of aquaculture on individual members of the household should be considered prior to the start of the activity.

A number of key issues will define whether, and for whom, the production of fish in seasonal water bodies is viable:

1. Access to credit: Groups undertaking rearing of fish to marketable size required group funds of Rs 5000 to 19,000 (~$116 to 442) not including the cost of labor; due to the conservative costing of the pond rental, this may be an overestimate (see item 4).

2. Pond rental: If farmers have to pay the pond owner with half of the harvest (as reported by some farmers), aquaculture may not be viable. With such high rates of rental, owning a pond or agreeing to use a community pond dramatically reduces the capital costs as well as the payback period. Development agencies promoting and farmers interested in commencing aquaculture have to critically consider the effect of pond rental on payback time and from this decide on the viability of aquaculture.

3. Availability of labor: The labor requirements for aquaculture fall mainly during the wet season when farmers are busy with their crops. If ponds are situated far from the homestead, night-time guarding may be necessary. In most of the trials conducted young male family members simply slept on the side of the pond to deter would-be thieves. Social customs dictate that it is unacceptable for women to guard ponds, and when only women's groups were involved in aquaculture a watchman was normally employed. The high labor requirements in guarding the pond, makes aquaculture most feasible in areas where excess labor is readily available or where theft is not a big problem.

4. Inputs: Agricultural and livestock by-products must be available in aquaculture. In the trials conducted, the farmers themselves decided on the stocking density of the fish and the levels of inputs used. Mustard oil cake and rice bran were purchased. For the financial analysis, cow manure was com-

puted at the rate it can be bought locally, but in reality the group members supplied the manure from their own livestock. Farmers should have sufficient livestock (cow, buffalo, ox) to produce about 35 kg manure $ha^{-1} \cdot day^{-1}$ or have money to purchase it.

5. Species of fish stocked: Faster growing species such as common carp and silver barb are most suitable for aquaculture in seasonal water bodies. Slower growing species are best stocked as advanced fingerlings if these are available the first time water becomes available.

6. Water availability: The duration of water availability is a key determinant of success. The time required depends on the species and size of fish stocked and the level of inputs, but in the experiments conducted, no trials of a duration of less than four months (120 days) were deemed to have succeeded.

7. Fish survival: Survival is also an important determinant of financial success, hence it is important to ensure that seed stocked is of good quality.

8. Livelihood considerations: The current livelihood strategy of the farmers needs to be taken into account. The net profit derived from 0.5 ha of rice paddy amounts to -Rs1500 to 10,000 on irrigated land, and about -Rs500 for dry land per year (Dr. V. Singh and Dr. K.P. Singh, IBRFP(E) pers. com.). Vegetable production on irrigated land can produce an income of Rs -1500 per year whereas the income from the trials ranged from Rs -5000 to Rs -46,000 per 0.5 ha. The level of expenditure and risk may be lower for paddy farming than for aquaculture but the labor requirements are higher. These considerations are important in determining whether aquaculture is a good option for individual families.

The existing aquaculture recommendations in India are derived mainly from research-station based development of technology for perennial water bodies. Currently the Indian government and research institutions promote mainly financially capital intensive aquaculture technologies suitable for wealthier farmers. The institutional context currently provides little incentive or support for aquaculture initiatives appropriate to resource poor farmers. Problems in the process of developing and disseminating aquaculture technological innovations in India have been widely recognized since the early 1990s (Appaji 1991; Sivasankar et al. 1991; Suresh and Selvaraj 1991), poor farmers rarely achieved the expected yields and little consideration is given to their circumstances, socio-economic context, and resource-use priorities.

Participatory research systems such as those employed here, with a pro-poor agenda, are attempts to refocus aquaculture options by working directly with farmers groups, in coordination with government research and development agents (Haylor 1997). The demonstration of the success of aquaculture systems, relevant to the needs and circumstances of the poor, may help to influence the support schemes, which were conceived and implemented by the Departments of Fisheries across the region to support aquaculture development. They can also provide recommendations relevant to the needs of farmers associated with bilateral development initiatives such as the IBRFP as well as influence the efforts of NGOs to support the livelihoods of the poor.

It is now widely acknowledged that participatory approaches involving effective co-ordination of innovative partnerships such as those reported here are most likely to lead to successful strategies for aquaculture development. These commonly include a process of finding out what people need and want, starting small and focusing on low levels of risk, and using local knowledge and resources produced locally to develop appropriate strategies (Friend and Funge-Smith 2002).

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