

## **Carp production in seasonal water bodies in Eastern India**

**Submitted to Asian Fisheries Science March 2000.**

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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 ( $P < 0.05$ ) higher rate than IMC and common carp grown from fry. Silver barb grows to significantly ( $P < 0.05$ ) smaller sizes than common carps and IMC grown from advanced fingerlings. Capital costs ranged from Rs2400-10,500 (\$56-244), variable costs from Rs2850-8950 (\$66-208) per cycle. The species of fish and their size at stocking are important for ensuring success. Common carp and silver barb can grow fast enough to get to marketable size in a seasonal pond, whereas IMCs should be stocked at 14-16cm length if expected to grow to marketable size during the wet season.

Key factors for the success of aquaculture in seasonal water bodies are access to credit, production enhancing inputs and water bodies that hold water for more than 120 days of the year. The availability of low cost labour and the current livelihood strategy of the farmer are 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 focuses 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 with limited access to water for irrigation and only few livestock. Most belong to the scheduled castes or tribes, and in contrast to vegetarian higher castes, fish form an important part of the diet for these communities. For aquaculture to contribute to poverty alleviation amongst these marginal communities, integrated approaches that suit and enhance their current livelihood strategy need to be explored. And recommendations suitable for 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.

It is a process project in which farmers decide the activities undertaken as the project proceeds. Farmer research support committees (Matsya Anusandhan Sahayak (MAS) Committees) 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. Membership includes members of farmers' group, the chair of farmers' group, community organisers from the 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 important constraint was the lack of information on the use of seasonal water bodies for fish production. The use of temporary water bodies for aquaculture is restricted by the poor availability of larger fingerlings or fast-growing species of fish, which can grow to a marketable size in the duration of 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 farmer demand, the project investigated a number of options for producing fish in short season water bodies. This paper reports on 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 has 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 of the ponds and experiments.

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

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 date of harvest was agreed between farmers and project staff on the basis of water level and staff 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. Manure was added 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. SSP and urea were mixed with small amounts of manure and left for one night before being sprinkled onto the surface of the pond.

Advanced fingerlings (trials 10-17) were treated with 250-500g potassium permanganate (amount depending on number of fingerlings stocked), which was 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 judged that the fish were stressed or suffering from disease.

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

Each pond was sampled 4-5 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 15mm) when they were larger. A randomly selected sub-sample of 20% of the fish were measured from the tip of the mouth to the tip of caudal peduncle and weighed (using a Salter EK 1200g, A & D Instruments Company Limited compact digital balance, d=0.1g) and the remainder released back into the pond. Water quality parameters were measured in the late morning (10AM 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 record 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 from the knowledge that one basket contains about 25kg of cow manure (G. Dutta, IBRFP(E) Aquaculture Specialist, pers. com.).

Costs of all local materials and services used for the financial analysis were obtained from farmers and triangulated from a number of sources, including the District Fisheries Officers of the Department of Fisheries, IBRFP staff, and market surveys. After the trials, farmers' groups all participated in a 'network meeting' to share the research results. The labour required for all activities associated with table size fish rearing detailed at the meeting farmers are used in the current analysis.

The statistical software Minitab was used for data analysis.

## 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 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 significantly ( $P < 0.05$ ) 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 when grown under farmers' conditions. 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 ( $P < 0.05$ ) smaller size than common carps and IMC grown from advanced fingerlings. There were no significant difference between the size of fish at harvest of IMC grown from fry and silver barb.

Because of the different length 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 ( $P < 0.05$ ) higher SGRs than IMC reared from advanced fingerlings. No relationship was found between survival rate, SGR, and weight at harvest, and stocking density, or feed and fertiliser 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 fertilisers. 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 Rs2400-10,500 (\$56-244), depending on the number of fish stocked (and hence the approximate size of the pond). Variable costs ranged from Rs2850-8950 (\$66-208 per cycle). Production enhancing inputs (feed and fertiliser) constituted the largest proportion (26-59%) of the variable costs, whereas fish seed represented 12-48%. In the financial analysis the local cost of manure was used, however in all trials the individual group members supplied the manure. The amount of manure used in the trials varied between 12-87kg ha<sup>-1</sup> day<sup>-1</sup>, the average was 35kg (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 varies. About 70% of the groups own their own ponds, and these belong to two categories. In groups based on kinship, related families form a group and manage the family pond. In villages which have been allocated a water body as a common property resource from the local block development office, all households from the village are members of the group and via elected committees manage the pond. The remaining 30% of ponds are owned by individual group members, who allow aquaculture sharecropping. Most of the groups involved in the trials own their own ponds, only one of these (Kaipara Nabayub Sangh, trials 16 and 17) is a common property resource belonging to the whole village. However, the

remainder work on a sharecropping system where 20-50% of the harvest belongs to the pond owner (G. Dutta IBRFP, pers. com.). To assess the viability of aquaculture for non-pond owners, it was assumed in the financial analysis that farmers had to pay a share of the harvest to the pond owner, and the worst case scenario of 50% was used. Using this estimate, pond 'rental' comprised 71-93% of capital costs.

The important components of labour inputs were pond preparation, feeding and security (see Figure 6). In areas where theft is a priority constraint (e.g. Northern Purulia trials 1-8, 10 and 14-17) the total labour cost accounted for up to 83% of gross margin if pond guarding was costed at the local labour rate. However most groups did not pay for the guarding of the pond, as a young male group member would generally sleep on the side of the pond.

In the present worst case scenario, four of the trials were unprofitable. Three of these were the trials involving IMC grown from fry. The unprofitability of the trials can be attributed to the low survival of the IMC grown from fry (14, 16, 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 apart from number 16 and 17 become profitable. The rate of pond rental has a significant effect on the payback rate. Figure 6 shows the effect of lowering the pond rental on the payback cycles for a number of the 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 can pay back the initial investments within three 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. Because of the dry nature of the environment, the most profitable crops are those requiring irrigation, for which the farmers either have 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 affects IMC and not common carp or silver barb. At the time of the Farmer Network Meetings, all groups stated that they intended to grow fish again without support from the project. At present, one year later, an on-going survey is following up the level of retention of aquaculture without support from the project, and with what impacts on their livelihoods.

## 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. Seasonal ponds were previously not used for aquaculture in the project area because no information existed 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 are available.

The present study demonstrated that farmers from some of the most disadvantaged socio-economic groups in India can successfully produce fish of a marketable size in remote, rural, seasonal water bodies. The research provides information on the likely growth and survival of different species of fish, capital and operating costs, labour requirements and likely returns. The states of Bihar, West Bengal and Orissa (the site of the research) 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 (260-3600kg fish ha<sup>-1</sup>) are comparable to figures reported by (Edwards *et al.*, 1991) from the AIT Aquaculture Outreach Programme in Northeast Thailand. Here farmers harvested between 530-2392kg ha<sup>-1</sup> pond area from polyculture of common carp, silver barb, IMCs and Chinese carps. The Outreach ponds ranged in size from 400-2500m<sup>2</sup> and fish were stocked at similar to higher densities (1.2-2.4 fish m<sup>-2</sup>) 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 integrated aquaculture practices in seasonal and perennial ponds. At comparable stocking densities to those used in India (0.8-1.7 fish m<sup>-2</sup>), farmers in Bangladesh obtained generally lower production levels (200-900kg fish ha<sup>-1</sup>). However in Bangladesh, the level of production enhancing inputs added were low at 700-1200kg cow manure ha<sup>-1</sup> compared to 2200-17,200kg, and 1-30kg oil cake ha<sup>-1</sup> compared to 185-1300kg ha<sup>-1</sup> in India. (Gupta *et al.*, 1999) describe 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<sup>-2</sup>) and with more than three times as much manure and feed per unit pond area after 7 months harvested 1000-3000 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.



Because of their relatively slow growth rate, IMC have previously been reported to perform badly in seasonal water bodies (Morrice, 1998). In E. India, similar to 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 relatively low with this species.

Aquaculture has the potential to diversify the livelihood of the farmer. However, the space taken up for the use of a pond could be used for agricultural production. Because of the dry nature of the region, if they can afford a pump and have access to electricity, most farmers 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 other issues than just finances. For example in the Northeast Thailand, more than 40% of farmers participating 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 at times of religious ceremonies, weddings, or offer them as presents to friends and relatives. Fish provides a relatively low-cost alternative to chickens or goats, 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. And aquaculture as an added livelihood activity may increase the farmer's portfolio, thus spreading risk and increasing options.

Fish culture is not very labour 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 involved adopting aquaculture in seasonal water bodies used both their own and hired labour, but on average the 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 was often reported as being no extra burden (Demaine *et al.*, 1999). At

time of pond preparation and harvest, aquaculture activities will be 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. Because of 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 finances, and major decision-makers in terms of investments. The introduction of fish culture may give rise to uneven distribution of the workload and the benefits for different family members, and the potential impact of the introduction of aquaculture on different 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 a marketable size required group funds of Rs 5000-19,000 (~\$116-442) not including the cost of labour. Because of the conservative costing of the pond rental, this may be an overestimate (see (4)).
2. If farmers have to pay half of the harvest to the pond owner (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 and thereby the payback period. Development agencies promoting, and farmers interested in commencing, aquaculture need to critically consider the effect of the pond rental on the payback time and based on this make a decision on the viability of aquaculture.
3. Availability of labour. The labour requirements for aquaculture falls mainly in the wet season when farmers are busy with their crops. If ponds are situated far away 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. Because of social customs, it is unacceptable for women to guard ponds, and when only women's groups were involved in aquaculture a watchman was normally employed. Because of the high labour requirements for guarding the pond, aquaculture may be most feasible in areas where excess labour readily available or where theft is uncommon.
4. Agricultural and livestock by-products must be available for use in aquaculture. In the trials conducted the farmers themselves decided the stocking density of the fish and the levels of inputs used. Mustard oil cake and rice bran was purchased. For the financial analysis the cow manure was costed at the rate it can be bought for locally, but in reality the individuals of the group supplied the manure from their own livestock.

Farmers should have sufficient livestock (cow, buffalo, ox) to produce about 35kg manure ha<sup>-1</sup> day<sup>-1</sup> or have money to purchase it.

5. The 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 at the time of the first water availability.
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 trials conducted no trials of a duration of less than four months (120 days) were deemed to have succeeded.
7. Survival is an important determinant of financial success, and it is therefore important to ensure that seed stocked is of good quality.
8. The current livelihood strategy of the farmer needs to be taken into account. The net profit derived from 0.5 ha of rice paddy amounts to between Rs1500-10,000 on irrigated land, and about Rs500 for dryland per year (Dr V. Singh and Dr K.P. Singh, IBRFP(E) pers. com.). Vegetable production on irrigated land can produce an income of between Rs1500 per year whereas the income from the trials ranged from Rs5000 to Rs 46,000 per 0.5ha. The level of expenditure and risk may be lower for paddy farming than for aquaculture but the labour requirements are higher. These considerations are important in the determination of whether aquaculture is a good option for individual families.

The existing aquaculture recommendations in India are mainly derived 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 with the process of developing and disseminating aquaculture technological innovation in India have been widely recognised since the early 1990s (Appaji, 1991); (Sivasankar *et al.*, 1991); (Suresh and Selvaraj, 1991), poor farmers rarely achieve expected yields and there is little consideration given to their circumstances, socio-economic context, and resource-use priorities.

Participatory research systems such as employed here, with a pro-poor agenda, are an attempt to refocus aquaculture options by working directly with farmers groups but in association 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 are 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 the influence the efforts of NGO to support the livelihoods of the poor.

### **Acknowledgements**

The East India Integrated Aquaculture Project (R6759) is funded by the UK Department for International Development (DFID) High Potential Systems Programme. The project works in participation with farmers' groups, associated with the Indo-British Rainfed Farming Project (IBRFP), in farm-based trials integrated with on-station research and contextual information collection. The IBRFP in Eastern India is a bilateral development project supported by the DFID to initiate a process of widespread and sustainable renewable natural resources development using flexible, cost effective and participatory approaches to improving livelihoods of poor women and men in rainfed upland area in West Bengal, Bihar and Orissa. The project has three main components:

- (a) the integrated development of farming systems in 250 'core' villages, involving identifying and testing technologies to meet the needs and priorities of poor men and women farmers; design, construction and management of productive assets and undertaking of other activities in groups; and generating institutional capacity in villages to ensure long-term sustainability;
- (b) spreading easily transferable technologies to 550 surrounding villages, using different extension methods and agencies;
- (c) creating awareness, changing attitudes and developing skills in state government agencies to enable them to work together, and with NGOs, in a participatory way with poor men and women farmers.

'This document is an output from a project funded by the UK DFID for the benefit of developing countries. The views expressed are not necessarily those of DFID. The authors would like to thank the IBRFP(E). Especially Mr J S Gangwar the project manager and Dr V Singh the State co-ordinator for West Bengal and the project steering committee including Steve Jones of Centre for Development Studies, Swansea, Mr Malholtra of Krishak Bharati Co-operative Ltd. (KRIBHCO) Noida, UP and Dr S Ayyappan Director of the Central Institute for Freshwater Aquaculture, Bhubaneswar, Orissa. We are particularly grateful to IBRFP(E) community organisers who supported and contributed to the work. Especially: Suwendu Singha Tapan Kumar Maity T K Mitra (Snr) Ms Gayatri Bowmik A K Bandyopadhyay (Snr) Vausafeudu Paul Amlan Mukherjee (Snr) Ms Pinki Singha Ms Chinu Banerjee S K Pradhan AK Biswas (Snr) SK Das and Sujit Pal. We are particularly indebted to the efforts of the groups of farmers who participated in the work, especially: Padalochan Novodipti Sangh, Khamatarn

Navatarun Sangh, Khamatarn Mahila Samiti, Adarshawad Sangh, Bamu Mahila Samity, Nabadaya and Kasidih  
Adiwasi Jankalyan Samity.

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### Tables, Figure captions and Figures

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 Junit 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.



Table 2: Details of trials.

| 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.          |

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

Table 4: The level of inputs (kg ha<sup>-1</sup>) 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.

| 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         |
| 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 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        |
| <b>Capital costs</b>              |             |               |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| 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         |
| <b>Total capital costs (Rs)</b>   | <b>4198</b> | <b>10,503</b> | <b>6497</b> | <b>5425</b> | <b>6550</b> | <b>6840</b> | <b>7499</b> | <b>6044</b> | <b>4343</b> | <b>8142</b> | <b>9862</b> | <b>7732</b> | <b>5280</b> | <b>5392</b> | <b>9520</b> | <b>2400</b> | <b>2520</b> |
| <b>Variable costs</b>             |             |               |             |             |             |             |             |             |             |             |             |             |             |             |             |             |             |
| 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 <sub>4</sub> (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         |
| <b>Total variable costs (Rs)</b>  | <b>4918</b> | <b>8518</b>   | <b>7101</b> | <b>5874</b> | <b>6856</b> | <b>7265</b> | <b>7785</b> | <b>7450</b> | <b>4065</b> | <b>5160</b> | <b>6431</b> | <b>3903</b> | <b>2936</b> | <b>5755</b> | <b>8938</b> | <b>2855</b> | <b>3418</b> |
| 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 Dutta pers. com.).

\*\*\* Total income - variable costs

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<br>(kg acre <sup>-1</sup> ) | Gross income (Rs acre <sup>-1</sup> ) | Gross margin<br>(Rs acre <sup>-1</sup> ) |
|------------------------------|--|---------------------------------------|--|
| 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                                     |

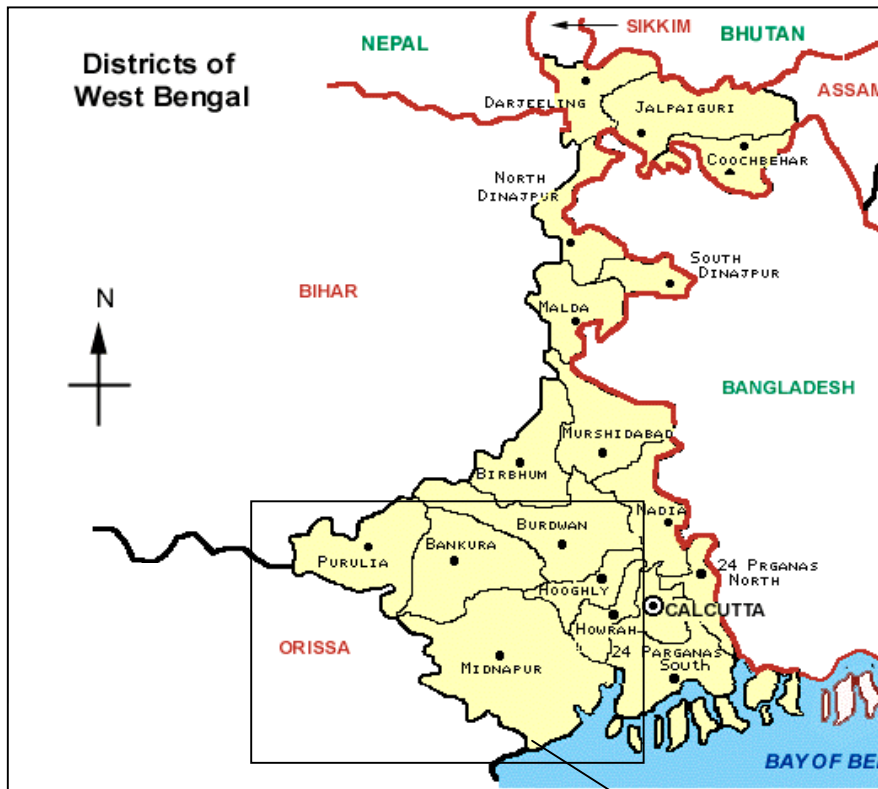


Figure 2: District in West Bengal, India



Figure 3: The location of research clusters in West Bengal

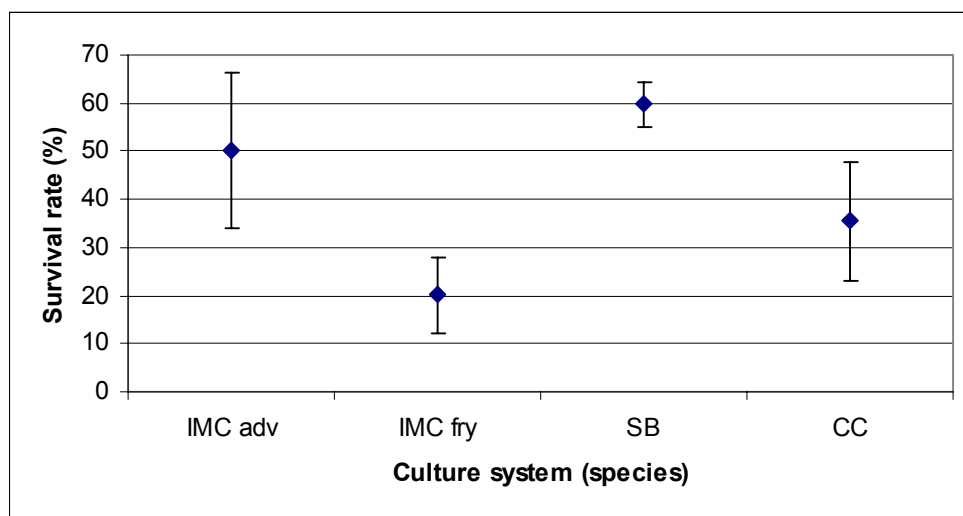


Figure 3: Survival rate, and 95% confidence intervals, of the different culture systems tested in Eastern India. IMC adv: Indian Major Carps grown from advanced fingerlings to table size, N= 4; IMC fry: Indian Major Carps grown from fry to table size, N = 4; SB: silver barb, *Puntius gonionotus*, grown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

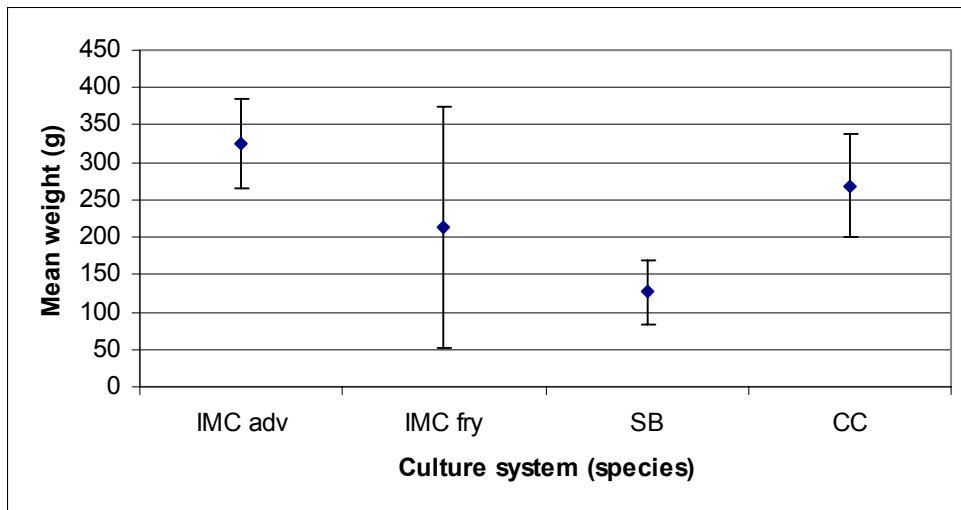


Figure 4: The mean weight at harvest, and 95% confidence intervals, for the different culture systems of the trials. IMC adv: Indian Major Carps grown from advanced fingerlings to table size, N = 4; IMC fry: Indian Major Carps grown from fry to table size, N = 4; SB: silver barb, *Puntius gonionotus*,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



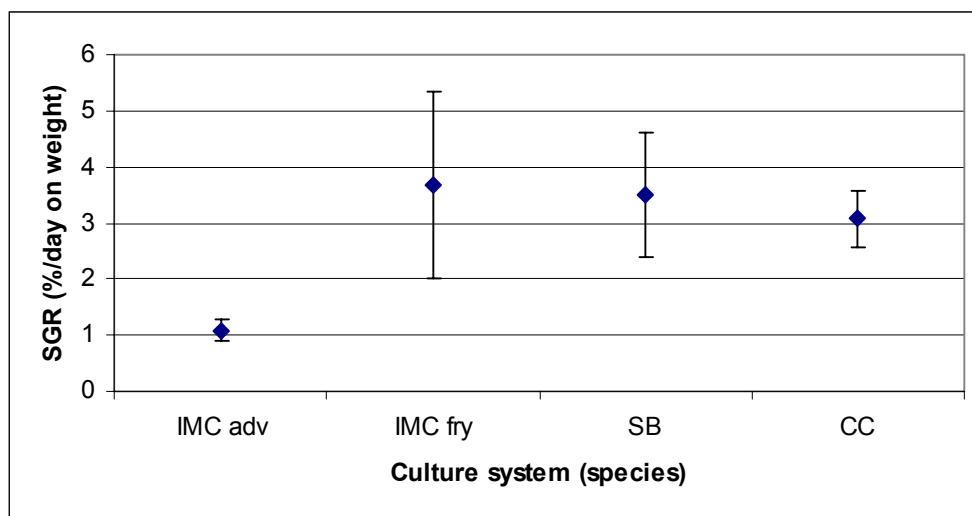


Figure 5: Mean specific growth rates (SGR) and 95% confidence intervals. IMC adv: Indian Major Carps grown from advanced fingerlings to table size, N = 4; IMC fry: Indian Major Carps grown from fry to table size, N = 4; SB: silver barb, *Puntius gonionotus*, grown from fry to table size, N = 5; CC: Common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

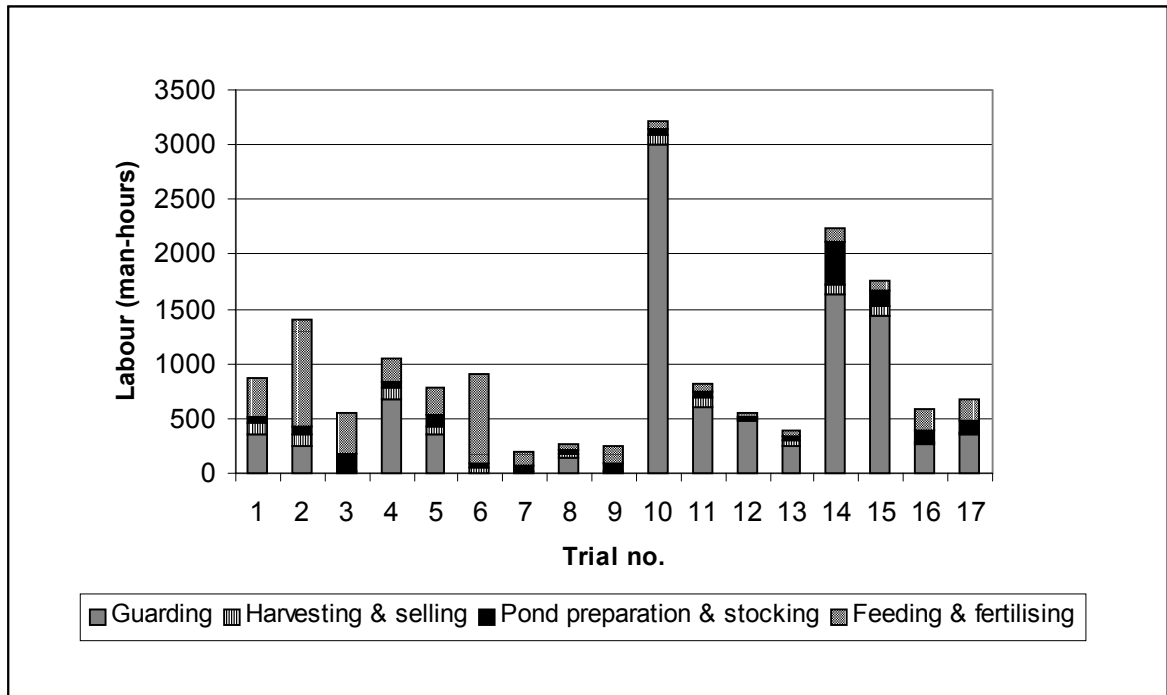


Figure 6: Different categories of work associated with the aquaculture trials.

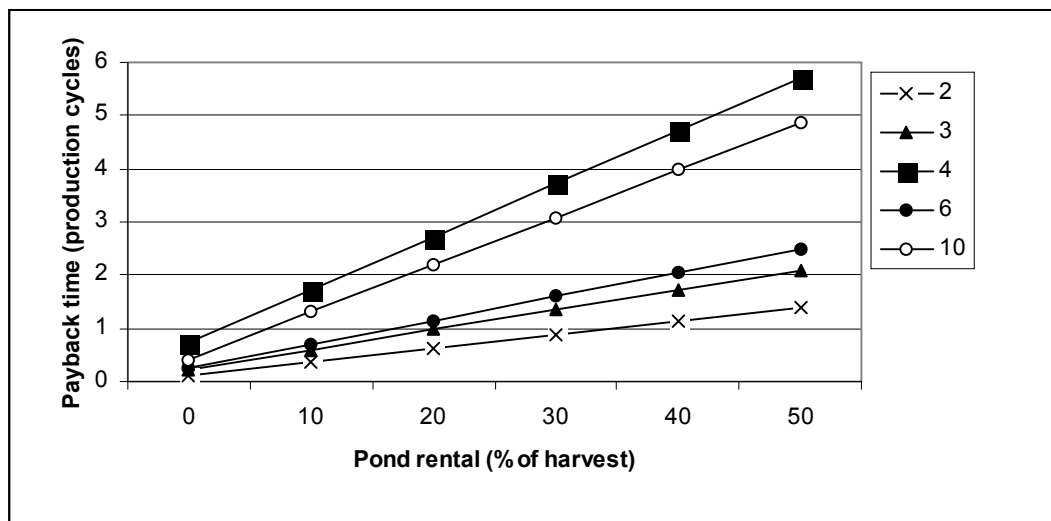


Figure 7: The effect of the rate of pond rental on the payback period for some of the trials (trials 2, 3, 4, 6, and 10, for details of the trials see Table 4).