Results of management experiments implemented in rice-fish systems in West Bengal, India as part of an adaptive learning approach.

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1 Introduction

Both rice and fish are immensely important to the livelihoods of the rural poor in Asia as both a source of nutrition and/or as a source of income. Rice and aquatic organisms, primarily fish, are considered to be the two main sources of food in this region. For example, it has been estimated by Hassan (2001) that rice constitutes as much as 60% of the daily food intake of the majority of Asians. Rice consumption in West Bengal is reported by the Government of West Bengal to be 139.68 kg per head per year compared to 160.8klg per head per year & urban 127.56 kg per head per year (1993-1994) in rural and urban areas of India respectively.

According to the report of World Fish Centre (WorldFish 2002) over 10 million hectares (ha) or 15 percent of the total rice land in Asia suffer from uncountable seasonal flooding of which over half are in Indian subcontinent mainly in Eastern India and Bangladesh. These areas are vital for sustaining and improving the livelihoods of millions of people who are dependent upon renewable natural resources in these countries. Because of the plentiful rainfall during the monsoon from June to September, rice becomes the principal crop in West Bengal, and much of South Asia, in the post monsoon period (referred to here as the wet season). In addition to the rice that is produced in these areas, the flooded paddy fields provide a natural habitat of various types of wild fish and can be stocked to increase fish production.

Fish is widely consumed in Asia, and certainly in West Bengal where consumption is estimated to be 15.6kg, in comparison to a figure of 9.0kg for the whole of India. It is considered to be the major source of animal protein for the majority of people in Asia and a major source of vital micro-nutrients (Govt. of West Bengal 2004, Demaine and Halwart 2001, Hassan 2001). Freshwater fish, because of its relatively low price, also represents a vital source of animal protein for lower income groups (FAO 2001), crucial in West Bengal where it is estimated that some 94% of farmers may be classed as poor (Economist, 2004).

West Bengal, being a major fish consuming state, requires some 1.18 million MT of fishes annually to meet the demand of its estimated 80 million population (Population Census, India, 2001). However the present availability of fish is reckoned to be around 1.16 million MT (figures for 2003/04). The shortfall in the requirement is met through import of fish from other Indian States. A huge quantity of fin and shell fish, 1.8 million tones, worth in the region of INR 5620.00 million in 2003/04, are also exported from West Bengal. Since there is a high demand for fish in both the domestic and export markets, increases in fish production by integrating fish culture into rice cultivation systems and/or improving the management of existing rice-fish systems can make an important contribution.

Rao and Singh (1998) have estimated that of the 42 million hectares of rice cultivated land in India, about 20 million hectares is suitable for rice-fish integration while Shyam (1998) considers that only 0.23 million hectares is currently being managed as rice-fish systems. Floodplain areas provide a predominantly freshwater environment for the culture of rice and freshwater fish and prawns[1] (flood plain wetland 0.04 million ha). Deep water rice area, such as the areas that were included in this study cover an estimated 11 per cent of the total rice land in India.

There are also large areas that are used for rice cultivation in eastern India remain non-irrigated and are therefore chiefly mono cropped. This means that the land is producing only one crop of wet season rice in a year. Since, there is little scope for increasing the amount of land under cultivation, its vertical expansion through integrated farming in single land area has become the obvious alternative. Within West Bengal the seasonally flooded deepwater rice area has been estimated as being approximately 0.6 million ha (Saha and Bardan Roy 2001). These areas are basins and depressions where rain or flood water accumulates during the monsoon.

The seasonally flooded deep water freshwater areas are distributed across three main river floodplains. Saha and Bardhan Roy (2001) have provided some estimates of the size of the floodplain areas. The Gangetic floodplains cover the deep water areas of Murshidabad, Nadia and Hooghly districts having 0.185 million ha (31 percent of the total seasonally flooded deep water area). The Teesta – Mahananda floodplains covering the districts of Coochbehar, North Dinajpur and northern part of Malda. This floodplain has a deep water area of some 0.028 million ha, constituting around 5 percent of the total seasonally flooded deep water rice lands. The third floodplain is the Damodar-Kanksabati. These floodplains cover the districts of Midnapore and Birbhum and have a total area of 0.102 million ha. (16 percent of the total seasonally flooded deep water area).

Apart from the seasonally flooded freshwater rice fields, areas along the coastline are also used for wet season rice cultivation. Saha and Bardhan Roy (2001) describe these coastal

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[1] In accordance with FAO, shrimp refer to those caught or cultured in saline waters while prawn is used to describe those caught or cultured in freshwater.

floodplains as covering the saline areas in the districts of South 24 Parganas and North 24 Parganas and Howrah and have a total area of some 0.284 million ha. (48 percent of the total seasonally flooded deep water area). These areas are mainly mono-cropped in terms of rice cultivation and would traditionally often remain fallow during the rest of the year due to high salt content of the soil associated with non-availability of irrigation water (see MRAG *et al.* 2003 for more details). Rice-fish culture in coastal saline areas aims at utilizing the fallow period for short duration brackishwater fish culture without affecting the subsequent rice crop in the same plot during the wet season. It is estimated that in West Bengal alone there is a total brackishwater area of 405,000 hectares (Ganapathy, 1989), a significant proportion of which could be suitable for fish/shrimp culture or the culture of fish/shrimp and saline tolerant rice varieties.

Overall there are a variety of culture practices undertaken with regards to rice cultivation in West Bengal (see MRAG *et al.* 2003 for examples). Regardless of the practice, in all cases increasing the productivity of the resource system[2] represents best means for increasing food production, badly needed to provide both food and income for the rural population. Integration of fish into the rice cultivation practices through enhancement initiatives offers possibilities for increasing land productivity through increases in diversification and in overall yields and income generating potential from the resource system. One of the important factors that have influenced the utilisation and development of rice -fish farming of the State, is the socio-economic status of the rural poor community. Agriculture as well as fisheries are generally considered a low profession in India and are therefore practiced mainly by the members of lower caste groups. These rural communities are generally characterized by low levels of literacy, poverty and generally relatively low standards of living conditions.

Enhancement provides an opportunity to increase the income generated from the system and/or provides fish for household consumption. Enhancement of rice-fish systems, through stocking, can increase overall yields and substantially increase income from the system and, where fish is cultured alongside rice, the rice yields can be improved. It has been estimated that integrating fish culture into rice cultivation fish can increase the yield of rice by around 4 – 10 percent (e.g. WorldFish 2002, IIRR 2000, Sinhababu *et al*. 1984, Bardan Roy *et al*. 2001). Reasons for the increase in rice production include the fact that fish consume large quantities of weed, worms, insects, larvae and algae, which are either directly or indirectly injurious to paddy, resuspend nutrients and have a fertilization effect (e.g. Datta *et al*, 1986).

[2] Resource system is used here to describe the system as a whole including the biological, physical, social, economic and institutional aspects.

Rice-fish culture in India has been practiced for almost 1500 years and has developed from low input systems to become more intensive (Ali, 1990). However, in many cases the integration of fish with rice culture has been constrained by both technical and institutional factors (Mohanty *et al.* 2004, WorldFish 2002). Experience has suggested that, while enhancements have the potential to yield substantial benefits, the actual outcomes (in terms of yield, distribution of benefits and institutional stability amongst others) are often different to those initially expected (Lorenzen and Garaway 1998, Cowan *et al.* 1997, Garaway 1995, Hartmann 1995, Samina and Worby 1993). It is often said that the results from field trials are less than those of experimental trials (e.g. Mohanty *et al*. 2004). The underlying reason for these unexpected outcomes is uncertainty about the resource systems. This uncertainty manifests itself as (a) limited prior knowledge of local conditions and (b) the complexity of environments into which enhancements are introduced.

Adaptive learning approaches have been shown to have the potential to improve the management of enhanced fisheries. This is because of both the need to reduce the uncertainty associated with their management and the nature of the resource systems. Adaptive learning approaches involve using existing, or creating through management actions, variation in management (either spatially or temporally) and analysing responses to this variation to gain information about management. Previous studies (e.g. Garaway *et al*. 2002 and Lorenzen *et al*. 1998b) have indicated that the variation in management that already exists between management regimes could be used to provide information that could inform and improve management. Active experimentation, where contrast is created in management, can potentially yield even greater benefits or provide the information more quickly (Garaway *et al*. 2002 and Peterman and McAllister 1993).

1.1 Scope and objectives

The objective of the project was to test the applicability of the adaptive learning approach that had been developed in southern Lao PDR in other resource systems. The testing would provide an opportunity for developing sustainable resource management systems rice-fish systems through community based management. The project was implemented by Central Inland Fisheries Research Institute, Barrackpore and the Departments of Fisheries and Agriculture of the State Government of West Bengal in collaboration with World Fish Centre, Penang, Malaysia and MRAG Ltd, London. This project, funded through the UK Department for International Development Fisheries management Science Programme (FMSP) was conducted between June 2004 and May 2005. The project was based on the adaptive learning approach and provided an interdisciplinary and integrative action research programme for community-based resource systems in India. The project provided an opportunity to (i) evaluate the management approach of community based fish culture in seasonally flooded rice fields in selected sites of West Bengal, India (ii) to determine if improvements in management leading to more socially equitable and economically viable systems of community based fish culture in seasonally flooded rice fields can be achieved through participatory and adaptive learning processes and (iii) to quantify the extent of these benefits accrued by the stakeholders of the ecosystems, notably the poorest sectors who are dependent upon the resources.

This report will describe the experiments undertaken as part of the process of implementing the adaptive learning approach in West Bengal (see the adaptive learning www.adaptivelearning.info and FMSP www.fmsp.org.uk websites for more details on the other parts of the process). The aim of the experiments was to provide a better understanding of the resource systems and to generate new information about fish and rice systems that would be relevant to the needs of the stakeholder groups involved in the process, and in the management of these waterbodies.

1.2 Location

The project was implemented in the eastern state of West Bengal (Latitude 21^{0}38”N – 27^{0}10”N and Longitude 85^{0}38”E – 89^{0}50”), where rice farming and fish culture have long formed an important livelihood component to millions of farmers. West Bengal has a total area of 88551 square kilometres (km) and is associated with the floodplains of a number of major river systems including the Ganges, Damodar, Rupnarayan, Kansabati, Haldi, Mayurakshi, Subarnarekha, Silabati, Ichamati, Churni, Mahananda, Teesta, Torsa, Ajoy, Jalangi an Bidyadhari. At the south of the state the Bay of Bengal bounds around 750 km coastline.

2 Methodology

This section describes how the experimental sites were chosen and how the learning strategy (including management experiments) was selected and implemented.

2.1 Selecting the sites

Project sites were selected based on the information collected through survey in association the officials from the Government of West Bengal at State, District and Block level. After selecting a set of preliminary sites, a series of participatory exercises with farmers, members of local Govt. bodies, officials of Block Development Authorities were conducted. This process (described in more detail in MRAG, 2004) resulted in the selection of three freshwater sites (at Moyna, Kamardanga and Mohantiki) and one brackishwater site (at Tangramary) that were considered suitable for inclusion in the project activities. The other sites were not selected simply because the timing of culture and cultivation meant that it would not be possible to implement any activities at the site within the time available. The locations of the four selected sites within West Bengal are shown in Figure 1.

Figure 1 Location of the project sites in West Bengal, India.

Moyna (located at Latitude $22^{0}40"$ N and Longitude $87^{0}50"$E) in East Medinipore district consisted of 6 plots: Gopal Chak (50 ha), Dakshin Changra Chak (50 ha), Janaki Chak (8 ha), Mathuri Chak (65 ha), Charandas Chak (40 ha) and Baital Chak (60 ha) that were used for rice culture by some 1100 farmers. The Kamardanga site (Latitude $23^0$10”N and Longitude $88^0$20”E) was a village within Hooghly district where there were two plots: Dhamar beel (80 ha), and Kamner beel (30 ha). These plots were used for rice, jute and vegetable farming by some 350 farmers. The last of the freshwater sites, Malandighi (Latitude $23^0$30”N and Longitude $87^0$20”E) was a village in Burdwan district. The plot here was known as Bhagaban bundh and activities at this site involved 30 farmers.

The single brackishwater site was at Tangramari village (Latitude 22^0 40” N and Longitude 88^0 55” E) in North 24 Parganas. At this site there were 38 plots ranging in size from 0.26 to 0.52 hectares. Wheras at the freshwater sites the fish culture required farmers to manage a common property resource, at Tangramari the culture could be undertaken by individual farmers/households (see MRAG *et al*. 2003). At this site the 38 households were in the project.

2.1.1 Meteorological conditions at the four sites

The Climactic conditions of East Medinipore, Hooghly, Burdwan and North 24 Parganas districts are tropical. The climate can be divided into two seasons: a ‘wet season’ comprising the monsoon and mild winter season and a hot, summer ‘dry season’. The dry season starts from January and extends until about the end of May. The wet season begins with the monsoon period in June until around September followed by a winter period that continues up to January. The seasons can be seen in the meteorological data for the four sites showing the atmospheric temperature and rainfall (Figures 2 to 5). The meteorological data was collected in each case from the Block Agriculture Department, State Government of West Bengal.

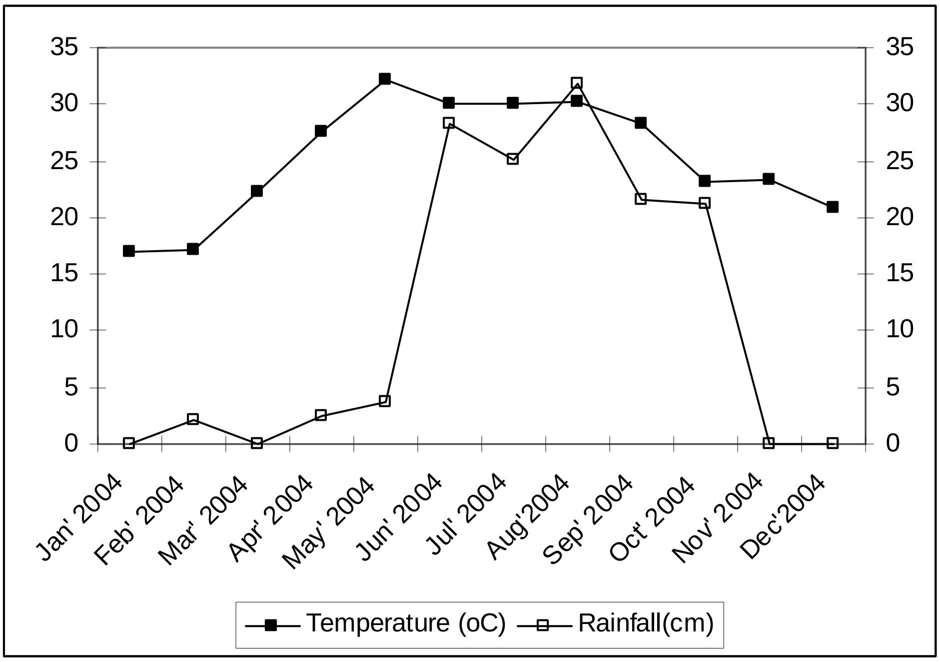


Figure 2 Atmospheric temperature and rainfall at Moyna (figures for 2004)

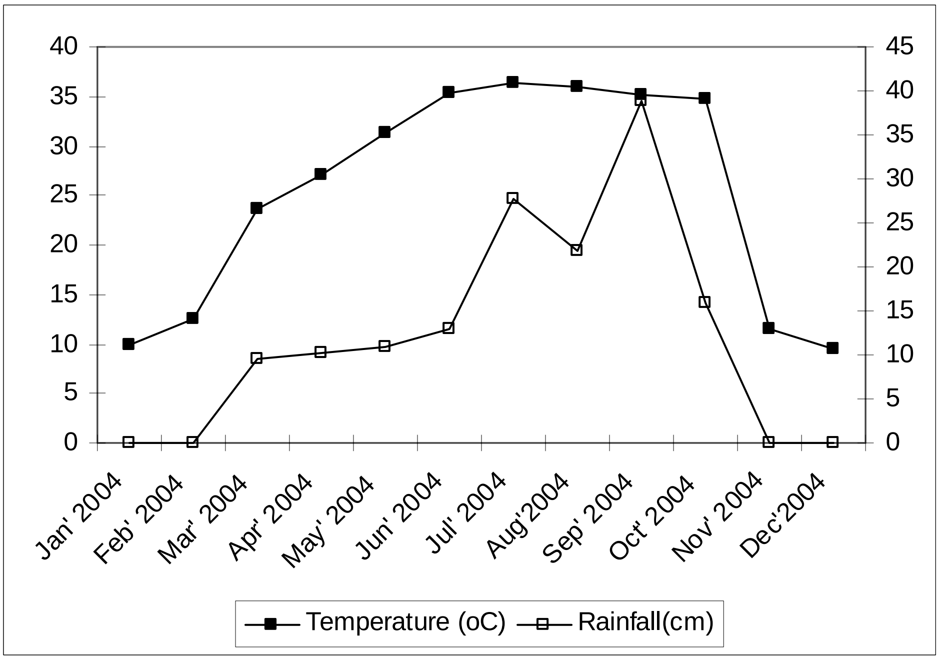


Figure 3 Atmospheric temperature and rainfall at Kamardanga (figures for 2004)

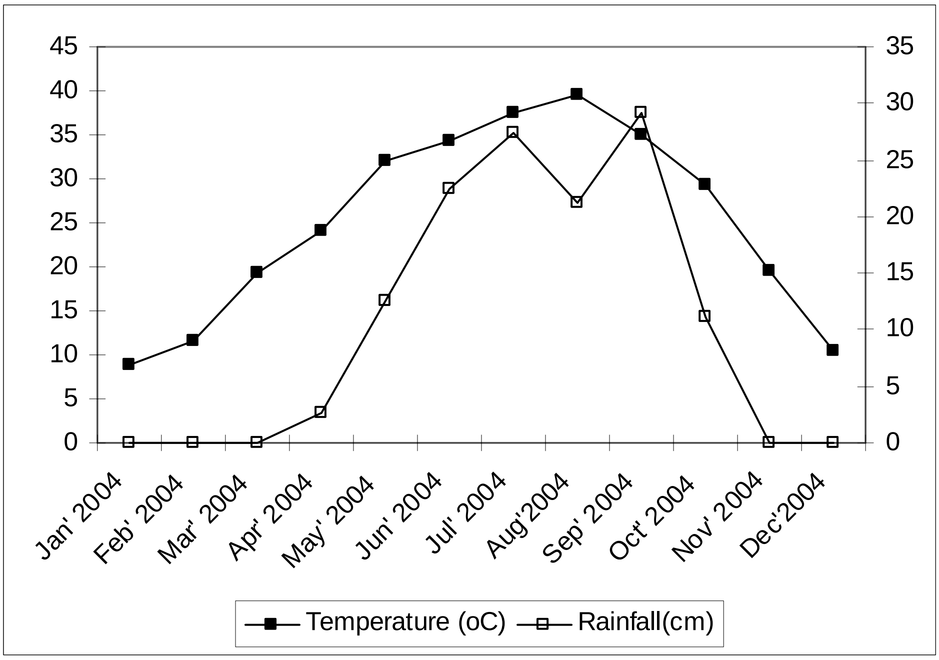


Figure 4 Atmospheric temperature and rainfall at Malandighi (figures for 2004)

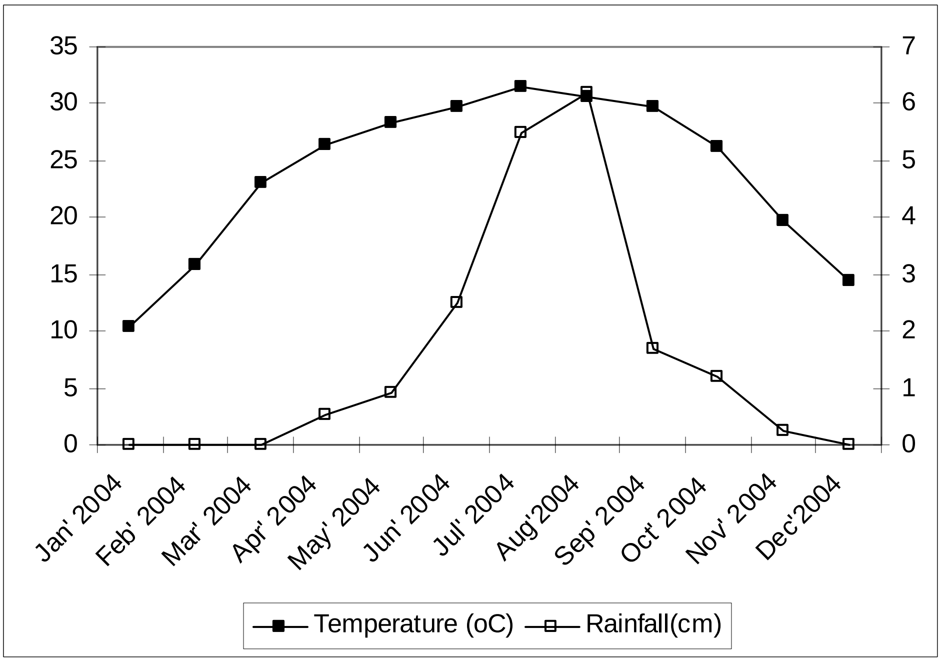


Figure 5 Atmospheric temperature and rainfall at Tangramari (figures for 2004)

In addition to the temperature and rainfall data, data was collected at the Moyna site on the light intensity during the culture period (Figure 6). As can be seen, as the season moved towards winter, the temperature and light intensity were both decreasing at the site.

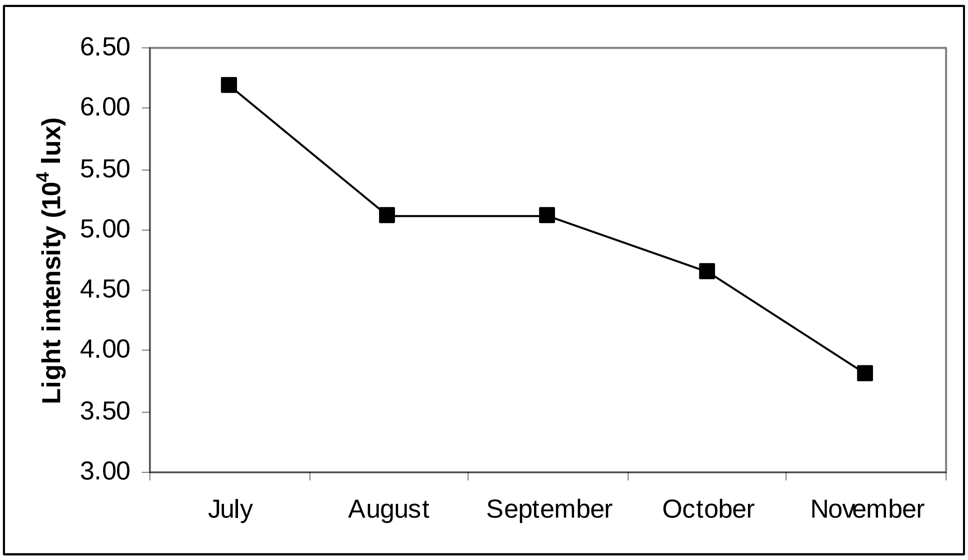


Figure 6 Mean monthly light intensity at the Moyna site during 2004.

2.2 Selecting the learning strategy

The process of selecting a ***learning strategy*** (see Garaway and Arthur 2004 and Arthur 2004 for more details on the learning strategy) that could generate information and reduce key uncertainties associated with the resource systems and their management involved filtering out from all the uncertainties identified during the rapid appraisal (see MRAG 2004) those that were not relevant or were unsuitable for other reasons. This process and the criteria that were used to select are described below. The process was designed to identify what information needed to be generated and shared and what existing information could be shared in order to remove constraints and improve management. The learning strategy should enable multiple learning objectives to be included in a single strategy and prevent often scarce resources being wasted on collecting information that is either not relevant or that is not utilized for other reasons.

2.2.1 Identifying uncertainties.

The first stage in developing the learning strategy was to consider the types of uncertainties associated with management. The results of the rapid appraisal (MRAG *et al.* 2003) together with information on rice-fish systems from other sources were used to identify uncertainties. The objectives and needs of resource users, as determined through consultation during the appraisal, were crucial to the identification of many of these uncertainties. Only those uncertainties that had some relevance to the priorities of the resource users or would benefit this group indirectly were considered any further.

The uncertainties identified included those associated with the biology of the resource system, such as most suitable species to stock, technical aspects such as feeding, fertilizing and disease control and institutional aspects such as the distribution of benefits from the resource system. The list of relevant uncertainties is given in Table 1 below.

Table 1 Uncertainties identified during the rapid appraisal.

Uncertainties identified
Optimal harvesting strategies
Prevention of illegal fishing
Seed quality
Seed sources
Fish marketing
Employment opportunities for the landless poor
Benefits to the landless poor
Distribution of benefits from rice-fish systems
Costs and benefits of management systems
Seed size
Optimising inputs (feed/fertiliser/pesticides)
Stocking densities
Species mixes
Suitable rice varieties

These uncertainties provide a series of potential ***learning options***, i.e. the subjects about which information needs to be shared with the relevant stakeholder group. Some of this information will already exist so simply needs to be shared but where it does not exist there may be a pressing case to use management experiments to generate the information.

2.2.2 Classifying and discarding learning options

Having identified relevant uncertainties, the next stage was to identify if and how the uncertainties can be reduced and whether they should. This process of prioritising and selecting the uncertainties to be addressed through management experiment and the sharing of existing knowledge was based on the process described in the adaptive learning guidelines (Garaway and Arthur 2002), and illustrated in Figure 7.

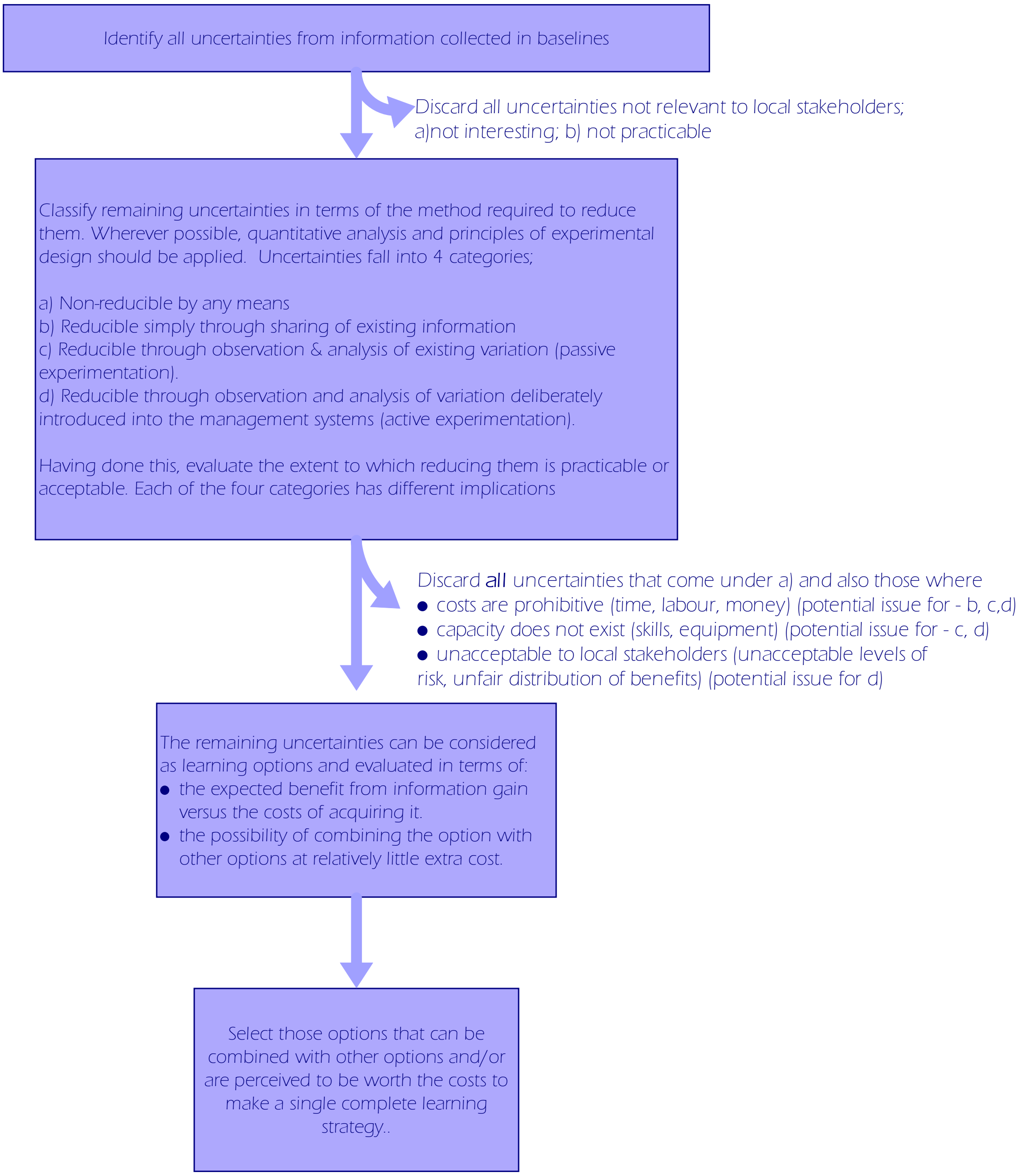


Figure 7 The process used to select the learning strategy (from Garaway and Arthur 2002).

The process as applied in West Bengal is described in more detail in MRAG (2004) but will be described briefly here with reference to both Figure 7 and Table 2. Having identified all uncertainties (box 1, Figure 7), a first cut was made whereby those uncertainties that had little relevance to resource users were discarded together with those uncertainties that it was felt that it would not be possible to address within a project of this size (see column two of Table 2).

The second step was to classify the identified uncertainties as learning options. Learning options can be classified in four ways, as described in box 2 of Figure 7 (and listed below). For the uncertainties identified the result of this is shown in Column three of Table 2.

a) Those for which information does not exist and where there is no existing variation in management, or variation that can be created, to provide it.
b) Those for which the information already exists and which can be reduced through the sharing of this information.
c) Those that could only be reduced through the generation and sharing of new information that is obtained through careful site selection and the analysis of the variation existing between these sites.
d) Those that can only be reduced using information that must be generated by creating variation between sites and subsequently analysing this variation.

Once they had been classified, each learning option was evaluated in terms of costs and benefits associated with reducing each the uncertainty. It is recognised that the method used to reduce each would differ and therefore each would make its own demands. Active experimentation, where variation is created, can potentially allow for faster learning than passive, because of the control over contrast that it allows. However, with active experimentation the costs are likely to be higher and active experiments can be much more difficult to implement. Thus the options had to be carefully evaluated in terms of what reducing the uncertainty would entail and, associated with this, what the costs would be and how useful the information gained would be. The following criteria were therefore used in the evaluation of each of the options to reduce the uncertainty.

1. Costs (time, labour and money)
2. Existing capacity (skills and equipment)
3. Considered unacceptable to resource managers (unacceptable levels of risk or unfair distribution of benefits across sites)

It was important where active experimentation was being considered to ensure that experimental designs were fairly robust. This was because implementation would require a high degree of cooperation from farmers at each of the sites and it was recognised that implementation completely in line with the design and without mishap was unlikely. The options for active experimentation required a good deal of consideration and discussion as there were constraints imposed by the area of the waterbodies, cost of stocking/planting, number of potential sites, equity and whether the treatments could supply the necessary variation.

Having considered all the options and discarded some on the basis of the above criteria, the options in Column 4 of Table 2 remained. It was decided that it was possible to separate these into those that could be reduced through the sharing of existing knowledge and those that could only be reduced through the generation of new knowledge (Column five). It was therefore decided that as well as the experimentation in order to generate information, opportunities would be arranged that would enable the sharing of experience and knowledge both within and between stakeholder groups. This set of learning options therefore makes up the learning strategy and determines what information needs to be generated and what needs to be shared.

Table 2 Applying the selection process to the identified uncertainties

Uncertainties	Relevant?	Category of uncertainty	Cost, capacity and risk	Share information
Harvesting strategies	✓	b	X(3)	
Prevention of illegal fishing	✓	b	✓	✓
Seed quality	✓	b	✓	✓
Seed sources	✓	b	✓	✓
Fish marketing	X (A)			✓
Employment opportunities for the landless poor	✓*	c	✓	generate
Benefits to the landless poor	✓*	c	✓	generate
Distribution of benefits from rice-fish systems	✓*	c	✓	generate
Costs and benefits of management systems	✓	c	✓	generate
Seed size	✓	d	X(2)	✓
Inputs (feed/fertiliser/pesticides)	✓	d	✓	generate (feed)
Stocking densities	✓	d	X(3)	✓
Species mixes	✓	d	✓	generate
Suitable rice varieties	✓	d	✓	generate
Shrimp disease	X(A)			✓

✓* = of interest primarily to government agencies and researchers. A = not feasible within the project, b = reducible through the sharing of existing information, c = generation of information through passive means, d = generation of information through active means, 2 = capacity constraint, 3 = unacceptable risk or benefit distribution.

2.3 The experimental component of the learning strategy

The selection process resulted in a learning strategy composed of both active and passive experimentation to generate new information about biological, economic and institutional aspects of the resource system. In each case the uncertainty addressed is one that is relevant to the needs of the stakeholder groups involved (compare with Table 1). The experiment combined active experimentation to generate information about suitable rice and fish varieties as well as passive experimentation to generate information about the benefits and distribution of benefits from the systems as these options could all be combined with very little additional cost.

2.3.1 Active experimentation

The active experimental component of the learning strategy involved introducing changes to management practices in a structured way in order to create variation that, if sufficient, would generate the required information.

2.3.1.1 Rice cultivation

The active experimentation at the freshwater sites involved experiments on both the rice and fish components of the system. The rice experiment at the freshwater site was designed to investigate the potential of a promising variety of rice (*Jaya cross*) in comparison to the existing varieties grown. The *Jaya cross* variety was one that had been developed by farmers at one of the project sites. They had themselves crossed the improved *Jaya* variety with a traditional rice variety used at the location. The farmers found that the resulting, *Jaya cross,* variety provided good yields as well as improved resistance to pests. It is this latter aspect that is of particular interest as this variety could have great potential in rice-fish systems where the use of pesticides can affect the fish. In addition to the rice experiment would involve experimental plots at each of the freshwater sites to compare the performance of the *Jaya cross* variety with the varieties usually grown at each site.

At the brackish water sties it was decided that the saline-tolerant CS1010 variety, one which had not been tried by the farmers, would be introduced and performance compared with the traditionally grown varieties.

2.3.1.2 Fish culture

In terms of the fish culture component, in the freshwater systems an experiment was selected that would look at the benefits from stocking fast growing species such as silver carp (*Hypophthalmicthys molitrix*) and common carp (*Cyprinus carpio*) along with the Indian major carps catla (*Catla catla*), mrigal (*Cirrhinus mrigala*) and rohu (*Labeo rohita*) compared with relatively high value species bata (*Labeo bata*) and punti (*Puntius javanicus*).

The experiment was based on interest as to whether the composition of fish species stocked could be altered to meet the objectives of both the government and those managing the waterbody at the same time. While those managing the resources had invested heavily and were seeking to maximise the financial returns from the waterbody, the government, for reasons of production and food security, was keen to ensure that the yields from the waterbodies were maximised. This creates a potential trade-off between growing faster growing, but lower value, species or the slower growing, but higher value species. Analysis of existing data suggested that it might be the case that while yields of the faster growing species would indeed be higher, it seemed that there would not be a significant difference in the income from the two options. The experiment was therefore designed to test this hypothesis.

Initially it was much more difficult to identify possibilities for active experiments to implement at the brackishwater sites. These waterbodies are initially stocked with small, wild sourced brackishwater seed fish. Where hatchery produced seed are stocked it is tilapia (*Oreochromis mossambicus*), a species not approved by the government and therefore one we could not use in any investigation that are stocked in the greatest number. However because these systems are small, individually owned and abundant, they are ideal for replicated experiments.

Observations of culture practices had identified two areas that were of possible interest. It was noticed that the farmers were feeding fish and shrimp with a moist feed that essentially dissolved in the water. This meant that the food was less available to the animals and meant that the feed also acted more as a fertilizer than feed. There was therefore a possibility of introducing a technical change whereby the farmers are encouraged to convert the moist feed into a dried pelleted feed that would hold together better in the water. Secondly, it was observed that farmers were stocking with bhetki (*Lates calcarifer*), though at low stocking densities, because of the high market price for this fish. These fish are carnivorous and have a high impact on the small wild fish that enter the ponds from the wild during water exchange (see Section 3.3.4) as well as feeding on the small shrimp. However, by removing the small wild fish they might reduce competition and make more of the natural food available to the other cultured species. Because of the impact of these fish on the shrimp and because the small wild fish (which had a low market price) could provide an affordable food source for the poorest, it was considered interesting to look at the costs and benefits associated with this species. Together this provided a two factor experiment where trials could be done with the feed type (wet or dried pellet) and with the stocking mix (with *L. calcarifer* and without).

2.3.2 Passive experimentation

Passive experimentation did not require any changes being made to management practices. Instead variation that already exists was relied on to provide the contrast that would enable comparisons. The subject of the passive experimentation across the freshwater and brackishwater systems was the benefits and costs to user groups of the different types of management. This was of particular interest to the Indian government and WorldFish Center researchers, who were keen to extend and improve the management of rice-fish systems. The data relating to the passive experiment could be collected at relatively little cost additional to the monitoring of any active experimentation.

2.3.3 Experimental design

While the passive experiment relied on existing variation and therefore did not require treatments to be allocated, treatments to be identified and allocated for both of the active experiments (rice and fish).

2.3.3.1 Active experimentation – freshwater fish

The two treatments for the active freshwater fish experiments were made up from species commonly stocked in the area. These included the fast growing silver carp (*H. molitrix*) and common carp (*C. carpio*) or higher value species such as punti (*P. javanicus*) and bata (*L. bata*). These were stocked in addition to Indian Major Carps (*L. rohita, C. mrigala and C. catla*). These would then be stocked at a total density of 3000 per hectare. The compositions of the two treatments are given below in Table 3.

Table 3 The active experimental treatments devised for investigating the effect of species mix across the freshwater sites.

Treatment 1	Treatment 2
Rohu (25%)	Rohu (25%)
Mrigal (25%)	Mrigal (25%)
Catla (25%)	Catla (25%)
Punti (15%)	Silver carp (15%)
Bata (10 %)	Common carp (10%)

2.3.3.2 Active experimentation – brackishwater fish

The treatments for the brackishwater fish experiment were to be undertaken during the brackishwater fish and shrimp culture period (January to June – see Figure 25). The treatments were based on farmers using their own formulations of feed and stocking as they would normally but divided into four groups: moist feed with *L. calcarifer* stocking; moist feed without *L. calcarifer*; pelleted feed with *L. calcarifer* and pelleted feed without *L. calcarifer*. This would allow the effects of pelleting the feed and of stocking *L. calcarifer* to be determined. The pelleted feed was to be produced by the farmers themselves by passing their moist feed through a hand driven mincer (see Plate 1), dried and then broken into small pellets.

Plate 1 Farmers at Tangramari village producing pelleted fish feed for use in the active fish culture experiment at the brackishwater site (Photo: P.K. Pandit).

2.3.3.3 Active experimentation - rice

The rice variety *Jaya cross* was tried at all the three freshwater sites to evaluate its suitability and performance when compared with other traditionally used varieties. At the brackishwater site CSR 1010 was selected, again to be trialled against traditionally cultivated varieties. In each case the rice was to be grown in a number of small plots.

2.3.4 Allocation of experimental treatments.

For the experiments on fish production, the treatments were allocated randomly across all of the freshwater sites. Rice treatments were also randomly allocated at, or within, each of the sites with Jaya cross provided to the freshwater sites and the saline-tolerant CS1010 at Tangramary. As an example, the allocation of the treatments for the freshwater fish experiments is shown below in Table 4.

Table 4 Allocation of experimental treatments for the active freshwater fish experiments.

	Treatment allocation / number of rice plots								
	Dhamar beel	**Kamner beel**	**Janaki chak**	**Boital chak**	**Dakshin changra chak**	**Mathuri chak**	**Charandas chak**	**Gopal chak**	**Bhagabanbundh**
High value		√	√			√	√		√
High yield	√			√	√			√	

The passive experiment, looking at the distribution of costs and benefits from the different management strategies that were applied systems was an important objective of both the ICAR and the WorldFish Center researchers, who were seeking to promote rice fish culture more widely. Therefore an investigation of this subject was highly relevant. Allocation of treatments was not an issue and the rapid appraisal indicated that each treatment would have at least nine replicates (Table 5)

.

Table 5 Number of sites implementing each management system (number of replicates in the passive experiment).

	Private	Renting
Number of sites	38	9

2.3.5 Implementing the experiment.

Implementation of the strategy meant having to agree with the farmers the strategy and the treatment allocations as well as the roles and responsibilities of the different stakeholder groups in the process. Details of this are reported more fully elsewhere.

With both the rice and the fish experiments it was agreed that the farmers should be asked to contribute to the seed costs. It was agreed that the farmers would be responsible for paying 60% of the seed costs (both rice and fish).

2.3.5.1 Consulting communities.

The first stage in implementing the experiment was to consult with the farmers at each of the sites that had been selected. While the learning strategy had been selected on the basis of information provided by the communities during the rapid appraisal, it was important that they were consulted about the experiments that had been designed. This was to ensure that the villages understood what was planned and had an opportunity to discuss it and comment on the plans. The farmers could then assess whether the learning strategy was indeed relevant to them and therefore whether they wished to participate. At this stage farmers at one of the sites that had been selected, Pearypur, decided that they did not want to participate as they felt that the experiment was less relevant to their needs.

It was important that everyone was aware of what was planned, what information would be generated and what the roles and responsibilities of each stakeholder group would be as this would not only help increase understanding but would also make the experiment easier to implement. An agreement was drawn up with the farmers at each site that set out what each stakeholder group would contribute. In this, it was agreed that the project would cover 40% of the cost of stocking the waterbodies in accordance with the experimental design. CIFRI and State Government staff would assist the farmers in monitoring the experiments and would facilitate the sharing of the results with the farmers. In return, the farmers agreed that they would stock in accordance with the experimental design, would monitor the experiments and provide the data and would participate in activities designed to share experiences and knowledge.

2.3.5.2 Monitoring the experiment

The process of identifying uncertainties, agreeing the learning strategies and developing experiments leads naturally towards the development of a monitoring system. Because the information requirements have been defined as part of the process, it is possible to develop a monitoring system that meets these needs without imposing additional costs – time and other resources – in collecting data that will not be used. Monitoring of the experiments was the responsibility of the project staff (project coordinator together with district and block level staff from the Departments of Agriculture and Fisheries) as well as those managing the waterbodies. The monitoring was divided between these to ensure that those best placed to collect the information were the ones to do so. Standardised forms were developed with the assistance of project staff and were reviewed by the researchers to ensure that all the information relevant to the experiments would be collected. Monitoring included:

- Recording details of the stocking events. Information, including fingerling source and stocking mortality, was collected by the Project staff at each stocking event.
- Management of the waterbody. Project staff would meet with representatives of those managing the waterbody to discuss management of the waterbody, including details of management and any problems that had been encountered over the previous two months.
- Benefit sharing arrangements. Project staff met with representatives of those managing the waterbody to discuss the benefits from the management of the waterbody and how these were shared and with whom.
- Because of the dispersed nature of the sites and the fact that those managing the waterbody would be involved in the harvesting, and they were therefore best placed to monitor this activity, responsibility for recording catches and sales by species was with this group. To assist them, a standardised record book was provided so that they could record this information. The record book was checked by project staff when they visited to collect management and sharing information to ensure that it was being completed correctly (see Appendix A).

2.3.5.3 Stocking and seed supply

Stocking of the waterbodies at participating freshwater sites and distribution of paddy rice seed at all of the participating sites occurred from July 2004. Stocking was in accordance with the experimental design and waterbodies were stocked at a density of 3000 fingerlings per hectare with 3-5 centimetre locally sourced fingerlings. Fingerlings were transported in 25 litre aluminium hundries with approximately 100-125 fingerlings per hundry, a method commonly used for fingerling transportation in the area. Stocking was directly into the waterbody. In the brackishwater site, stocking occurred from February 2005 and farmers arranged the stocking themselves in accordance with the experimental design with fish seed obtained from the wild and from local traders and the market at nearby Hasnabad.

3 Results

The results section has been divided into freshwater and brackishwater and these are discussed in turn. Each section provides details of the resource system including biophysical aspects, economic and management arrangements and outcomes. The results from the active and passive experiments are also described.

3.1 Importance of fish at the study sites

Fish was found to be extremely important as a component of the diet and as a source of employment and household income at all of the sites. In terms of preferences, it was found that farmers and the landless poor showed a preference for small and wild fish while those that were considered wealthier preferred somewhat larger fish like carps. Most of the fish consumed by households was caught from the nearby canals, streams and flooded areas (66% in Malandighi,, 57.1 % in Moyna, 65 % in Kamardanga and 40.5 % in Tangramari). In addition to this wild-sourced fish, households also purchase fish from markets.

3.2 Freshwater systems

The freshwater waterbodies selected and who had agreed to participate in the management experiments were located at Moyna in East Midnapore district; Kamardanga in Hoogly district and Malandighi in Burdwan district (see also Figure 1). Details of the waterbodies at these sites are given in Table 6 below.

The waterbodies at Moyna and Kamardanga are similar in nature in that they are formed in depressions in flood prone areas that are seasonally flooded during the monsoon period and remain submerged for 4 – 6 months after that (during the wet season). In such areas, land ownership remains with farmers who produce a rice, or sometimes vegetable, crop during the dry season. However, during the wet season the individual land holdings are neither visible nor viable as the area takes the shape of a single large sheet of water. The waterbody, and the fish available in it become a common resource that, if it is to be managed, requires collective action. This is similar in nature to the resources described by WorldFish (2002).

At Malandighi the situation was a bit different with the waterbody, created by forming an earth bund around a natural depression only completely dried up periodically. Following the monsoon rains, the waterbody would be greatly enlarged and would be stocked at this time. The waterbody (and surrounding land) were under the ownership of a group of individuals so that the management system was essentially private with this group maintaining complete control over the system in both the wet and dry seasons.

The culture cycle at all the freshwater sites was the same with a crop of rice or vegetables in the dry season followed by simultaneous rice and fish in the wet season. The fish culture occurring at the same time as deep water rice cultivation following the flooding of the waterbodies in June/July by the monsoon rains. Seasonal land use at the freshwater sites is shown in Figure 8 below.

Table 6 Details of the individual waterbodies at the three freshwater sites

	Dhamar beel	Kamner beel	Janaki chak	Boital chak	Dakshin changra chak	Mathuri chak	Charand as chak	Gopal chak	Malandi ghi
Site	Kamardanga	Kamardanga	Moyna	Moyna	Moyna	Moyna	Moyna	Moyna	Durgapur
Area (ha)	80	30	08	60	50	65	40	50	08
Location	Hooghly	Hooghly	East Medinipur	East Medinipur	East Medinipur	East Medinipur	East Medinipur	East Medinipur	Burdhwan
Management*	R	R	R	R	R	R	R	R	P
Farmers involved (No.)	190	80	150	250	200	250	200	200	25

* management by rental (R) or private ownership (P). See MRAG 2004 for more details on the definition of the management categories

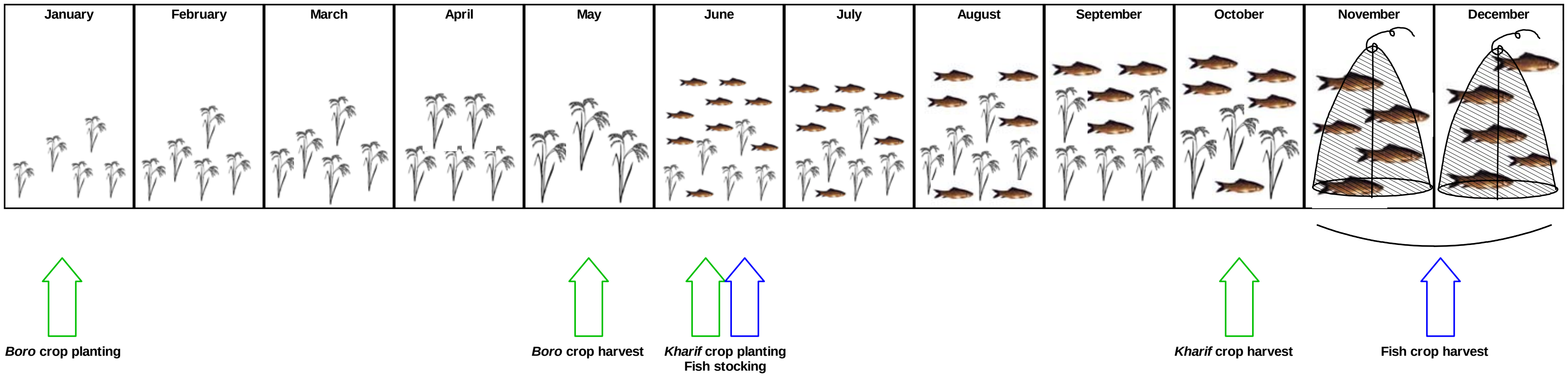


Figure 8 Seasonal calendar depicting the process of fish culture and rice cultivation at the site at freshwater sites.

The Block Moyna comprises some 84 villages within in East (Purba) Medinipore district of West Bengal. The area is characterized by large areas of low lands or saucer shaped depressions. Following the monsoon rains, the low-lying areas become inundated with water to form the deepwater areas. Fish was an important resource in this area with fish and prawn culture continuing to some degree all year round and with some 76% of farmers in the area having a household pond for fish culture. The network of canals that linked the waterbodies at this site with river channels, and which provided water for fish culture and irrigation also provided an important source of fish for household consumption for the landless and the rural poor (see Plate 2)

Plate 2 Example of the use of canals as a source of fish by the poor at Moyna (Photo: R. Arthur).

The importance of this resource to the poorer sectors of society was recognized by the local farmers who were reluctant to allow developments in these canals, such as cage culture, that would have potentially altered the access to and use of these resources.

Kamardanga under block Balagarh district Hooghly possess number of low lying floodplains. During the summer season the whole floodplains area dries up and the farmers cultivate summer rice (*Boro*) or vegetables. During monsoon these areas get inundated. Each of the resulting waterbodies have provided an opportunity for the development of simultaneous rice cultivation and culture based fisheries where the fishery makes use of the wild fish resources that use the waterbodies for breeding and shelter as well as introduced species. In this area more importance has been given to the rice crop by the farmers and fish was considered as secondary crop. This is due to the management arrangement where farmers individually cultivate the rice but for fish culture the waterbodies are traditionally leased.

Agriculture was considered to be the primary occupation of all the respondents at the freshwater sites (Moyna 59.0%, Kamardanga 65.0% and Malandighi 58.3%) followed by fish culture (Moyna 47.6%, Kamardanga 18.3% and Malandighi 66.6%). Kamardanga showed a markedly lower level of involvement in fish culture (with very little household fish culture) and this was to do with the caste of the villagers. At Kamardanga most of the households belong to a similar caste and one of the main occupations in the village is the production of curd which is traded and sold in markets as far away as Kolkata.

In terms of use of aquatic resources in Kamardanga village, the farmers and their households capture naturally occurring wild fishes and prawns in and around the rice fields during the wet season and towards the end of the season when the water recedes. Various methods, including local traps, cast nets and hook and line are used to catch fish during this period. In certain fields, where the drainage facilitates it, the farmers may create a small trap pond inside the field and harvest fishes from these at the end of the wet season. Typically a wide variety of wild fish species were reported to be caught using these methods including: *Channa striatus, C. marulius, C. punctatus, Anabus testudineus, Clarias batrachus, Heteropneustes fossilis, Notopterus notopterus, Amblypharyngodon mola, Ambassis sp., Colisa faciatus, Nandus nandus, Rasbora danicornis, Mastacembelus armatus, M. pancalus, Puntius sp. and Mystus vittatus*.

Malandighi belongs to the Kaksha block , Durgapur under Burdwan district (Figure 1). This is an extremely dry part of the state of West Bengal and the area is susceptible to frequent droughts. *Kharif* and *Rabi* rice crops are grown in this area due to the lack of irrigation facilities that mean the area is not sultable for growning *Boro* (pre *Kharif*) rice and the land remains fallow during the dry season (see also MRAG *et al*. 2004 for details of how conditions and resources affect land use). At the Malandighi site there were many landless households whose main source of income was as labourers and who also engaged in some rice cultivation and vegetable growing to support their household consumption needs.

3.2.1 Bio-physical characteristics

The sediment characteristics of the soils of Moyna (Table 7) indicates that soil texture of the impoundments were water retentive and conducive for rice cultivation. The pH ranged between 6.02 and 6.29. The nitrogen, phosphorus, organic carbon values depict productive range for good rice as well as fish production. The C/N ratio ranged from 10.0 to 13.3.

Table 7 Soil and sediment characteristics of the sites at Moyna.

	pH	Total Nitrogen mg/100g	Available Nitrogen mg/100g	Available P_2O5 mg/100g	Organic Carbon (%)	Free $CaCo_3$ (%)	C/N ratio	Sand (%)	Silt (%)	Clay (%)
Dakshin Changra Chak,	6.13	0.08	45.92	0.48	1.0	5.25	12.5	48.5	28.0	23.5
Baital Chak,	6.24	0.2072	45.08	1.04	2.25	4.25	10.85	50.1	27.9	23.9
Janaki Chak,	6.02	0.15	38.08	0.88	1.5	6.0	10.0	51.5	26.5	22.0
Gopal Chak,	6.15	0.23	43.28	0.93	2.5	4.75	10.8	47.0	28.8	24.2
Mathuri Chak,	6.29	0.09	45.12	0.59	1.2	5.31	13.3	52.0	24.0	24.0
Charandas Chak,	6.21	0.18	40.21	1.13	1.8	5.92	10.0	50.3	26.7	23.0

The soil and sediments characteristics of Dhamer and Kamner beel (Table 8) indicate that Dhamer beel could be potentially more productive than that of Kamner beel and in both cases the parameters in respect of pH, nitrogen, phosphorus, organic carbon and C/N ratio are observed to be suitable for rice and fish production.

Table 8 Soil and sediment characteristics of the sites at Kamardanga.

	pH	Total Nitrogen mg/100g	Available Nitrogen mg/100g	Available P_2O5 mg/100g	Organic Carbon (%)	Free $CaCo_3$ (%)	Course sand (%)	Silt (%)	Clay (%)	C/N
Dhamer beel	6.8	0.09	44.8	1.42	1.6	5.3	49.5	26.5	24.0	17.8
Kamner beel	7.1	0.07	43.2	0.9	1.1	4.2	50.0	27.0	23.0	15.7

The soil and sediment characteristics at Malandighi (Table 9) indicated that the site had lower productive potential compared to the more fertile freshwater sites elsewhere. This is not entirely surprising as the flooding at this site is due to monsoon rains and runoff with no nearby rivers that could provide a source of nutrient rich sediment. Soil texture analysis revealed that the water retention capacity at the site is good but the water level was observed to fall further than at the other freshwater sites. This was possibly due to a higher rate of evaporation, due in part to the smaller size of the waterbody.

Table 9 Soil and sediment characteristics of the sites at Malandighi

pH	Total Nitrogen mg/100g	Available Nitrogen mg/100g	Available P_2O5 mg/100g	Organic Carbon (%)	Free $CaCo_3$ (%)	Course sand (%)	Silt (%)	Clay (%)	C/N ration
6.8	0.08	32.5	0.48	1.4	3.25	48.5	28.5	23.0	17.5

Water sampling was conducted in each month at the same time of day during the culture period to measure a range of parameters including depth, pH and dissolved oxygen. The physico-chemical parameters of the water within the waterbodies and how these varied over the period at each of the study sites is shown in Figures 9 to 16. As can be seen, mean water temperature was decreasing over the culture period in line with the meterological conditions (see Figures 2 to 4). At the Moyna sites (Figures 9 to 12), dissolved oxygen levels remained fairly steady but fell over the last two months. This is perhaps due to the increased oxygen demand due to both the increasing fish biomass together with the decomposition of rice stalks following rice harvest. While there were fluctuations over time, all the parameters were seen to remain within ranges that were suitable for good fish growth.

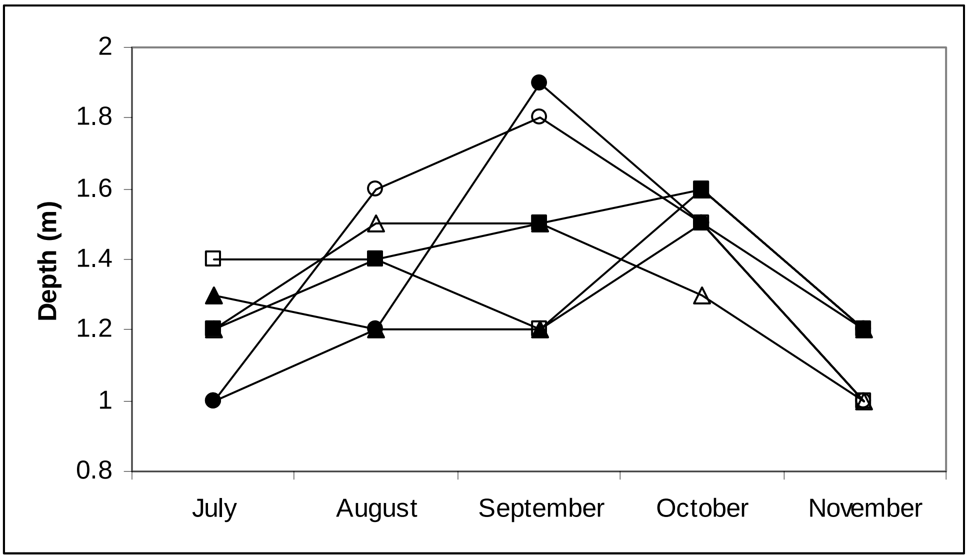


Figure 9 Variation in mean waterbody depth over the culture period (Gopal Chak ■; Mathuri Chak □; Charandas Chak ▲; Dakshin Changra Chak △; Baital Chak ● and Janaki Chak ○)

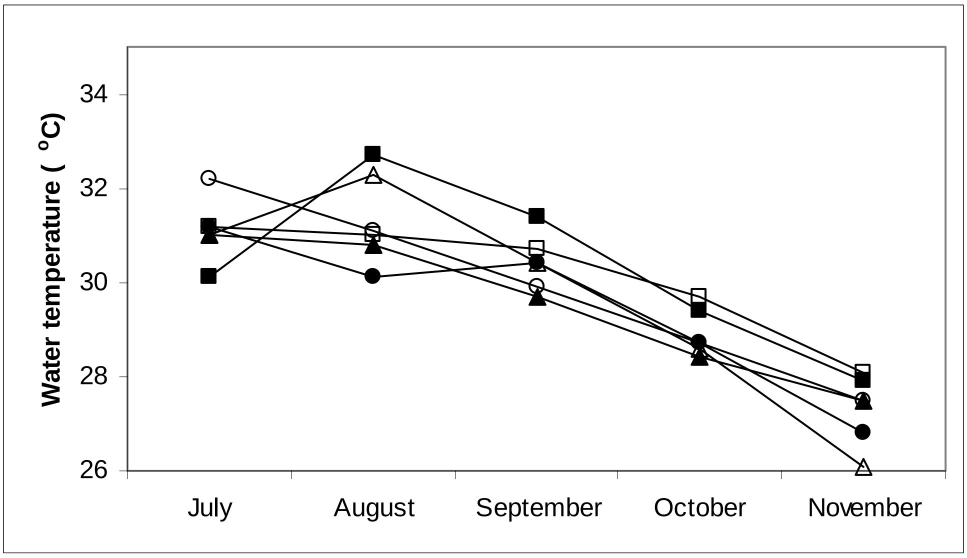


Figure 10 Variation in mean waterbody temperature over the culture period (Gopal Chak ■; Mathuri Chak □; Charandas Chak ▲; Dakshin Changra Chak △; Baital Chak ● and Janaki Chak ○)

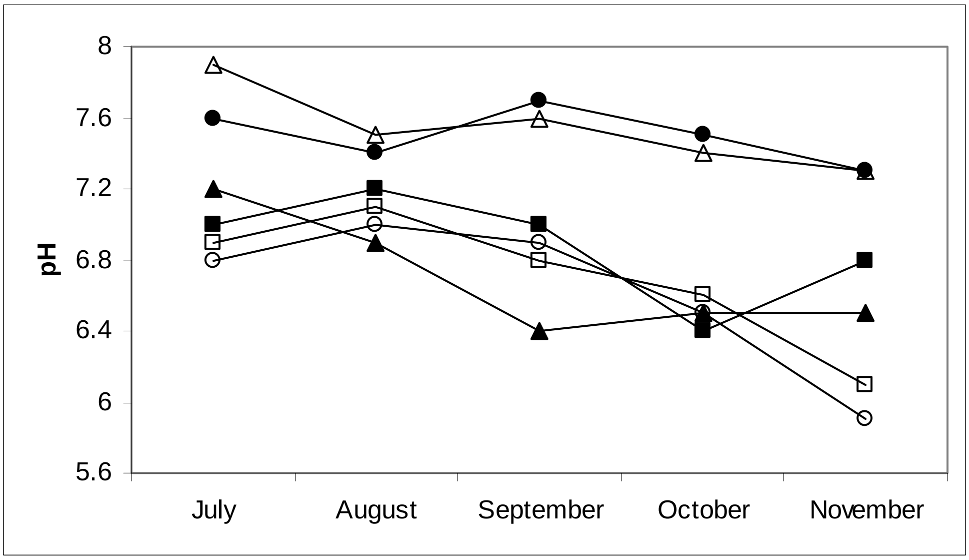


Figure 11 Variation in mean water pH over the culture period (Gopal Chak ■; Mathuri Chak □; Charandas Chak ▲; Dakshin Changra Chak △; Baital Chak ● and Janaki Chak ○)

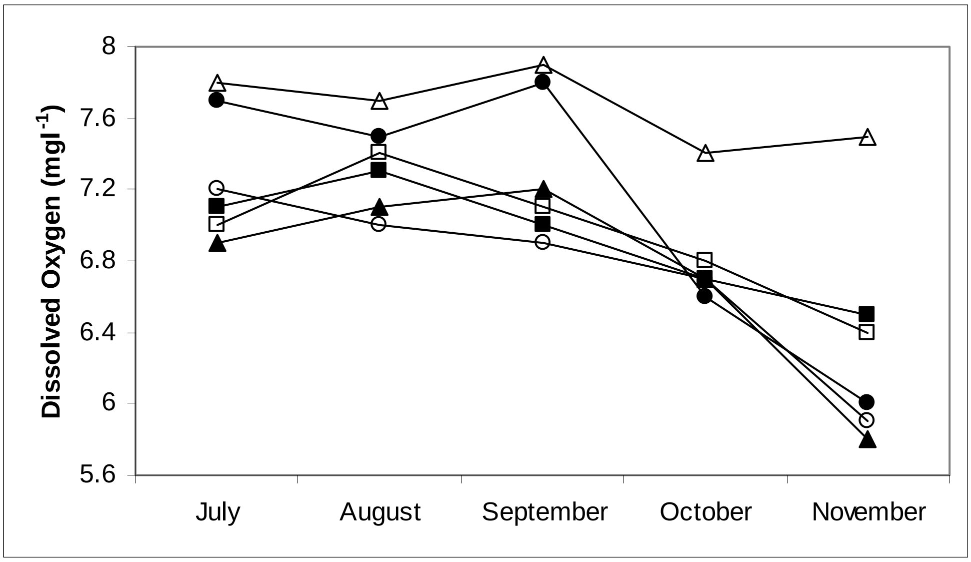


Figure 12 Variation in mean dissolved oxygen levels over the culture period (Gopal Chak ■; Mathuri Chak □; Charandas Chak ▲; Dakshin Changra Chak △; Baital Chak ● and Janaki Chak ○)

The physico-chemical conditions of Dhamar beel and Kamner beel (Figures 13 and 14) are generally similar to those at Moyna. Dhamar beel showed greater fluctuation in both depth and temperature due to the fact that the waterbody was smaller.

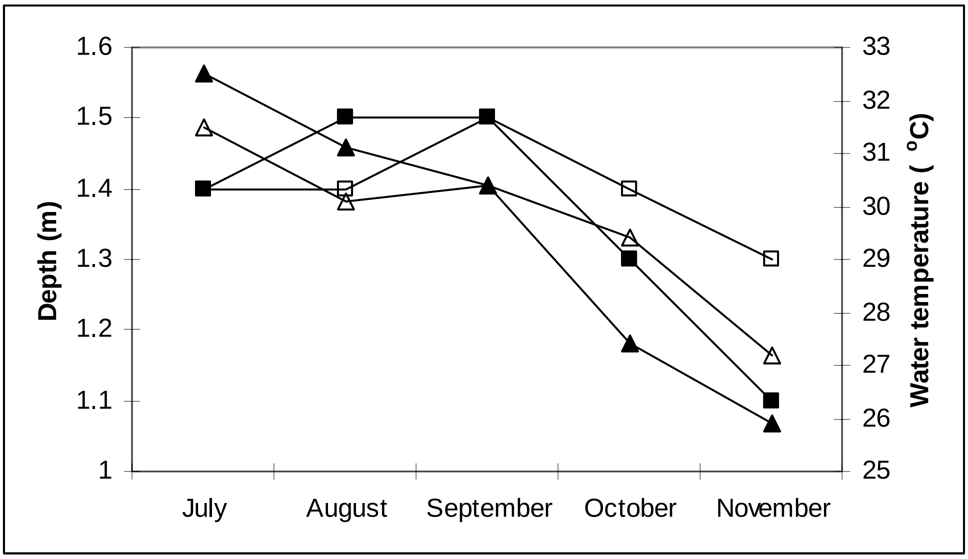


Figure 13 Mean waterbody depth (squares) and water temperature (triangles) for Kamner beel (outline) and Dhamar beel (solid colour) at Khamardanga.

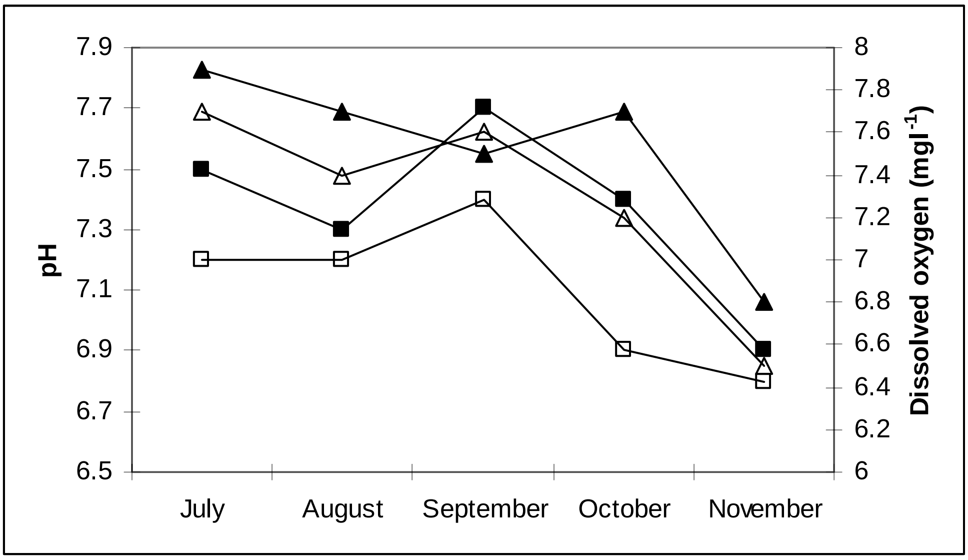


Figure 14 Mean pH (squares) and dissolved oxygen (triangles) for Kamner beel (outline) and Dhamar beel (solid colour) at Khamardanga.

The physico-chemical parameters of the water in the waterbody at Malandighi (Figures 15 and 16) varied over the culture period in a similar way to the other sites with depth and temperature decreasing over the culture period and pH and dissolved oxygen (DO) concentrations decreasing in the last months of the period. As mentioned, mean depth of the waterbody at Malandighi was lower compared to other sites. Over the culture period pH ranged form 6.7 to 7.6 and he DO between 7.1 and 7.9 at 1000 hrs.

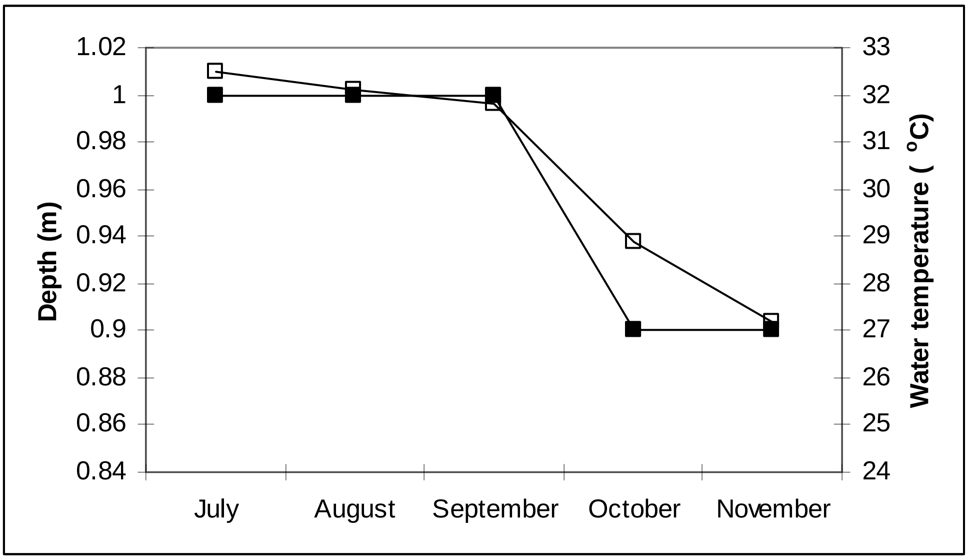


Figure 15 Variation in mean water depth (■) and mean waterbody temperature (□) over the culture period at Malandighi.

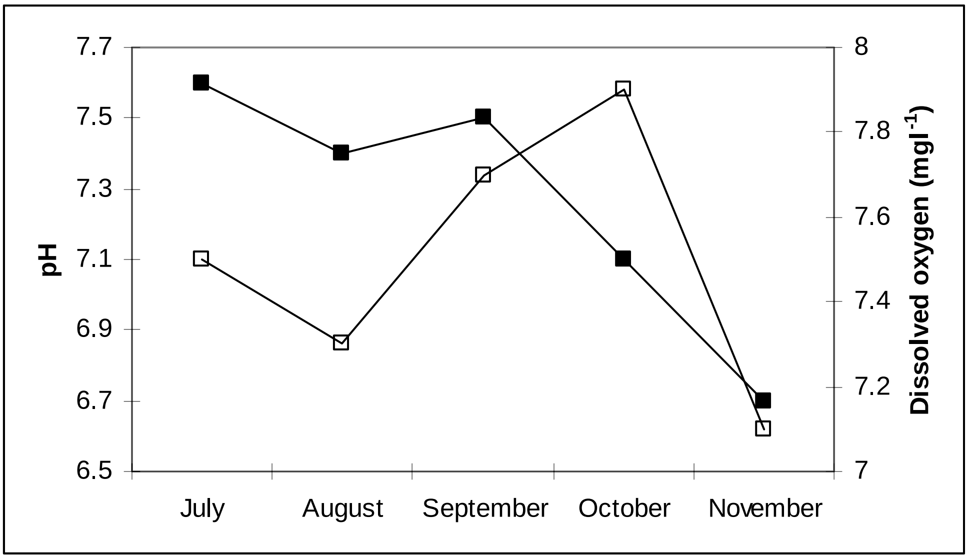


Figure 16 Variation in mean pH (■) and dissolved oxygen concentration (□) over the culture period at Malandighi.

The waterbodies that form during the wet season provide natural habitats for various aquatic resources including wild fishes and prawns. The yearly silt deposition and organic matter decomposition assist the natural productivity in the waterbodies by contributing to the natural growth of flora and fauna and providing an environment that is rich in plankton, periphyton and benthic organisms (see Table 10). The alutochthomus source nutrients as well as allochthonus source of nutrients coming through floodwater accelerates the growth these organisms in the waterbody, many of which are a good source of food for both the wild and cultured fish components of the system.

The submerged part of rice plants acts as a substratum for good growth of periphyton. After harvesting of rice above the water level, the submerged part of the rice plants remain undistributed continuing to provide the substrate necessary for this periphyton growth as well as a habitat within which many other species can find shelter. In addition, the rotting of the submerged part of the plants after harvesting releases nutrients into the water, increases the productivity of the system.

Table 10 Associated flora and fauna found in the freshwater rice–fish farming sites during the study and their relative abundance at each site.

Order/Group	Flora/Fauna	Moyna	Kamardanga	Malandighi
Chlorophyta	*Spirogyra spp.*	+++	+++	+
	Oedogonium spp.	++	+++	++
	Dreparnaldiapsis indica	++	+++	+++
	Stegeoclonium sp.	+	+	++
	Zygnema sp.	+++	+++	+++
	Characium spp.	+	+	++
	Selenastrum spp.	+++	+++	+
	Botrycocous sp.	+++	++	+
	Scendesmus spp.	++	+++	+
	Sorastrum sp.	++	-	-
	Pediastrum spp.	++	+	-
	Eudorina sp.	++	++	+
	Volvox sp.	+	++	+++
	Microspora sp.	++	+++	++
	Protococcus sp.	+++	+	+++
	Ankistrodesmus sp.	+++	++	+++
Cyanophyta	*Anabaena spp.*	+++	++	+++
	Gleotrichia spp.	-	+	++
	Oscillatoria spp.	++	++	++
	Spirulina sp.	+	-	-
	Tetrapedia sp.	-	-	-
	Polycystis sp.	+	+	+
Desmids	*Docidium spp,*	++	+	+
	Cosmarium spp.	+++	++	++
	Euastrum spp.	-	+	-
	Closterium spp.	++	++	+
	Staurastrum sp.	+++	++	+
	Penium spp.	-	+	-
	Desmidium sp.	++	+	+
	Pleurotaenium sp.	-	-	++
Bacillarophyta	*Navicula spp.*	+++	+++	+
	Synedra spp.	++	-	-
	Cymbella spp.	++	+	+
	Pinnularia spp.	+	++	++
	Nitszchia spp.	+++	++	-
	Amphora sp.	+	++	+++
	Diatoma spp.	++	+	-
	Melosira spp.	+++	+	+
	Gyrosigma spp.	-	++	++
	Eunotia spp.	-	-	+
	Cocconeis spp.	+	+	+
	Frustulia sp.	-	+	-

Order/Group	Flora/Fauna	Moyna	Kamardanga	Malandighi
Protozoans	*Arcella spp.*	++	++	++
	Centropyxis spp.	+	+	+
	Difflugia spp.	++	+	++
	Paramoecium sp.	-	-	-
	Loxodes sp.	-	-	+
Rotifera	*Brachionus spp.*	+++	+++	+++
	Euchlanis spp.	+	+	-
	Testidinelia spp.	-	-	++
Oligochaets	*Branchiura sowerbyi*	++	++	++
Ostrocods	*Bosmina spp.*	+	+	+
	Eurycerus sp.	+	+	+
	Macrothrix sp.	++	+++	++
	Ceriodaphnia sp.	++	++	++
	Chydorus sp.	+	+	-
	Diaphanosoma sp.	-	-	+
	Leydigia sp.	+	-	+
	Cyclops spp.	+++	+++	+++
	Diaptomus spp.	+++	++	++
Crabs	*Paratelphusa spinigera*	+	+	-
	P. hydrodromus	+	-	-
Ephimeroptera	*Caenis sp.*	++	++	+
	Cloeon sp.	+	+	+
Diptera	*Culex sp.*	+	+	+
Odonata (Dragonfly nymph)	*Urothemis signata*	++	++	+
	Anax sp.	+	-	-
	Enallagma sp.	+	-	+
	Agria sp.	-	-	+
Masogastroda	*Pila globosa*	++	++	+
	Digonisostoma cerameopoma	+	+	-
	Bellamya bengalensis,	+++	+++	++
	Gabbia orcula;	++	++	+
Basommatophora	*Indoplanorbis exustus*	++	++	++
	Gyralus convexiusculus	+	++	++
	Lymnaea acuminata	+++	+	+

Overall it was observed that the plankton community at the Malandighi was not as rich or diverse as at the other two sites. This is probably due to a combination of lower nutrient levels and fewer opportunities for plankton species to become established as the waterbody was not as well connected to other waterbodies as at the other freshwater sites.

3.2.2 Management

The description of management practices in all the freshwater sites will concentrate on the period when both rice and fish are produced, i.e. the wet season. Management at the freshwater sites in both Moyna and Kamardanga during this period was based on a lease system with the waterbody leased out by a 'village development committee'. This committee is an example of an 'informal local governance institution'. The village development committee consists of between four and ten landowners from the site (the number on the committee is dependent on the size of the waterbody). The members of the committee are selected through a process of nomination among the landowners and typically the members represented those individuals that were felt by the group to be the most capable for the position.

The waterbody lease price is set at an auction and the lease is given to the highest bidder. At this point the renter (typically this would be an individual) is required to hand over 50% of the agreed lease price, the remainder being paid just prior to harvesting. Lease prices varied from 6,990 INR (Kamner beel) up to 500,000 INR (Dhamar beel). Analysis indicated that the size of the waterbody had the greatest effect on the lease price with larger waterbodies fetching higher prices. This is not surprising but at Moyna the relationship was very strong (Figure 17). Apart from arranging the auction, the other main role of the village development committee in the management of the waterbody is in settling disputes between the renter and landowners should they occur, an important role recognized for such institutions by Gupta (2001).

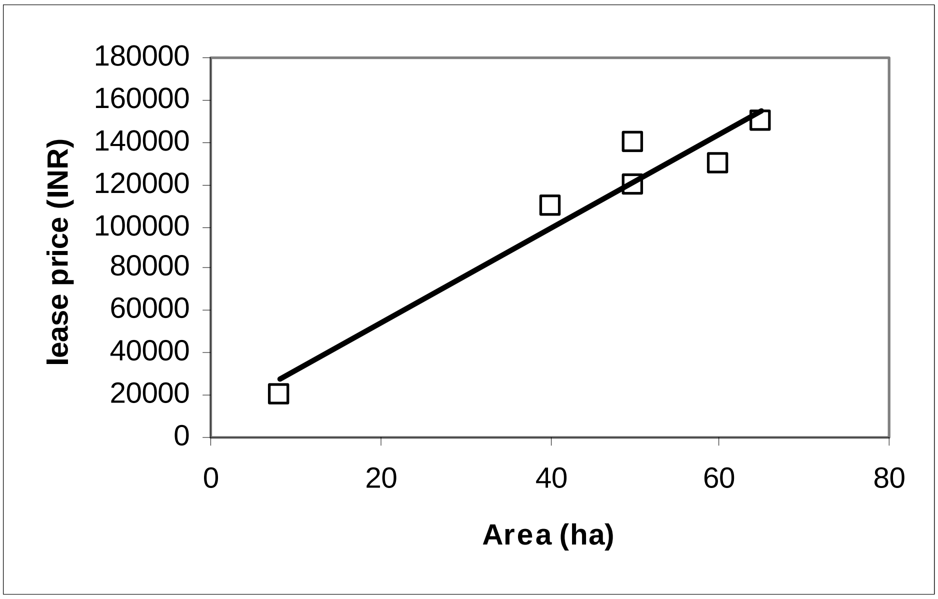


Figure 17 Relationship between lease price and waterbody area at Moyna (R^2=0.93)

The renter, in order to be able to lease the waterbody takes out a loan from a local fish wholesaler to cover the cost of the lease and required inputs. The terms of the loan agreement mean that the renter has to pay interest on the loan and, in addition, is required to sell an agreed minimum value of fish through that wholesaler, on which the wholesaler will charge a commission. The commission rate varies depending on the amount of fish that will go through the wholesaler with larger amounts being charged at a lower commission rate. Typically the rate is somewhere between six and nine percent. During rice-fish culture operation at Kamardanga the landowners are not permitted to catch any fish from the leased waterbodies. The renter is also not permitted to take any fish from the system before the harvesting time, as has been decided together with the village committee.

The waterbody at Malandighi was owned and managed by a local non-profit NGO who offered employment opportunities to the local landless poor. The NGO owned a single waterbody of 8 ha that completely dried only occasionally and that had been created by building an earth bund to enhance a natural depression. The local landless poor worked with the NGO under an agreement that provided a 50% share cropping option. Under the agreement the NGO provided land to the farmers along with all the inputs required for growing rice as well as fish and the landless poor contributed their labour in the production process in order to receive a 50% share of rice and fish crops.

3.2.3 Rice cultivation

While the fish culture operation was leased out as described, rice cultivation at the two sites, where it is possible given the water depth, is undertaken by the individual farmers within their plots. With the onset of Nor'wester across the region between the end of February and the middle of March, farmers till their individual farmers' plots using powered tillers. Immediately after the preparing the plots *Kharif* seed is directly broadcast at 150kgha^{-1} across the whole plot followed by leveling and after one month de-weeding and thinning occurs. The precise timings of these activities were dependent upon a number of factors including the morphometry and hydrology of the field and farmers assessed this based on their experiences. At the same time as the seed is broadcast, fertilizer is applied. At Moyna the fertilizer used was NPK at between 75 and 100 kgha^{-1} with a similar dose of Urea or NPK is applied to the plot again after one month. At Kamardanga the process was similar but with the fertilizer IFFCO applied at between 100 and 125 kgha^{-1} after the first month and Urea or IFFCO applied a month later.

The traditionally tall Indian deep water rice varieties are generally grown in areas similar to those in this study where monsoon flooding creates deepwater areas of varying depth (spatially and temporally) during the wet season (See Table 11). However, mainly due to the unpredictable nature of the monsoon flooding, these varieties often produce only a relatively low grain yield (1.5 – 2.2 tha^{-1}). In some areas floating rice varieties have been observed to have been used but details on these were not collected. The use of rice pesticides is generally not very intensive and pesticide use is confined only to seed bed preparation and during certain critical periods of pest infestations.

Table 11 Performance of major traditional floating rice varieties in the typical rice-fish areas of North 24 Parganas (N 24 Pgs), East Midnapore and South 24 Parganas (S 24 Pgs) in West Bengal, India (Source: Saha and Bardhan Roy, 2001)

Location	*Kharif* varieties	Mean yield (tha^{-1})
S 24 Pgs	*Bakui, Agniban, Sadamota, Malabati, Ramsail, Benemuti, Baneswar, Dudeswar, and Marishal*	1.8
East Midnapore	*Panikalash, Kakuria, Agniban, American queen, Bakui, Bhuta, Goda Bhutia, Kammoth, Amol selat and Hatipajra*	1.5
N 24 Pgs	*Mota, Sadamota, Hamai, Kumargore, Patnai 23, Gerimuri, Boirbal and Kamini*	2.2

In Moyna, where the *Jaya cross* variety has been developed and is cultivated, because this particular variety is disease resistant, no pesticide is required during the whole cultivation process. As the water level rises, because this is a variety suitable for deep-water cultivation, the rice grows with it, attaining a height suitable for, and according to, the resulting water depth. After 120-130 days growth the rice becomes ready for harvesting. At the time of harvesting the farmers harvest the rice using boats/rafts and by cutting the seed head part only from the top of the plant together with only about 0.3-0.5 m of the plant stem. The harvested rice is then taken to the farmyard, staged and then covered with polythene sheet as protection from the rain. Finally, after drying for 7 to 15 days, the rice is threshed, bagged and stored. The hay part (rice stems) are used as manure or as fuel in the kitchen oven. While there is a second, *Boro*, crop grown at Moyna the deepwater rice crop in the wet season is more important than the *Boro* crop and provides a greater profit (68.7% as opposed to 53.4 % for *Boro*).

The cultivation process at Malandighi was similar to that at both Kamardanga and Moyna but the main rice variety used at this site was *Swarna masuri*. Again, the rice seed was directly broadcast to the fields by the farmers, weeded, thinned and fertilized and tended during the growing season (around 130 days). Pesticide use was sparing and applied mainly during the nursing period.

3.2.4 Fish culture

The abundance of natural fish food in the seasonal waterbodies provides opportunities for developing culture-based fisheries. Fish culture, based mainly on natural production within the waterbody, is possible for four to six months in these waterbodies (see Figure 8). Alongside the naturally occurring wild fish production additional stocking by the renter, mainly of carp species including *L. rohita*, *C. mrigala* and *C. catla* (see also MRAG *et al.* 2004 for details of species stocked), occurs as the area becomes flooded following the monsoon rains, either by monsoon rain water or flood waters taken through canals from the nearby rivesr. At Moyna the Kangsabati, or Kansai, river flows adjacent to the farmers' fields so farmers are not always dependent on rain as the river can provide sufficient fresh water from upland areas.

At both Kamardanga and Moyna, the fingerlings for stocking are reared in small (0.8 ha) ponds that have been constructed within the waterbodies and that hold water all year round. These ponds (average depth around 0.6 – 0.9 m) are used to hold back fish that were considered to be too small to sell the previous year (from the middle of January to middle of the May, or until the arrival of monsoon) and for nursing the current years fish seed. In each pond about 1000 kg fry, fingerlings are stocked and fed daily with compost (see below) as supplementary feed at a rate of about 80 –100 kg per day. Some additional feeding with a mix typically containing rice bran, wheat flour, mustard oil cake and groundnut oil cake also occurs.

The ingredients for the compost (including, but not limited to, cow dung, oil cake, aquatic weeds and grass (see Table 12 for typical compost mix) are placed in earthen pits (typically 2.0 m X 1.8 m X 2.5 m). The bottom of these pits are covered with a polythene sheet to control leaching of the compost and the compost is left undisturbed for 18 –20 days. From the pits about 80 –100 kg are taken out in baskets and applied to the pond directly as feed for the fishes in nursery.

Table 12 Composition of compost applied to the fish culture ponds from January to June.

Ingredient	Typical proportion (%)*	Approximate cost (INRkg^{-1})
Raw cow dung	92.63	0.10-0.15
Rice bran	3.71	2-2.5
Mustard oil cake	2.27	7-8
Superphosphate	1.39	3

In cases where there is an indication of outbreak of any disease (for example, EUS or Myxosporidiosis), neem oil cake at a rate of 50 kg per bigha (1 bigha = 0.13 ha) is broadcast to the pond directly.

These nursery ponds are not always owned by the renter. In some cases the renter will also rent the nursery pond at the end of the year to keep fish for the next year but in other cases a farmer will stock or hold fish. Once the rental agreement is reached then the renter will purchase the fish from the farmer or the previous renter who own the seed. This provides some potential for conflict over an acceptable price to pay for the seed and where necessary the case is taken before the management committee for arbitration.

From the nursery ponds, the fish are released in the wider waterbody when the water level is high enough rice is considered to have grown sufficiently that the bigger fishes cannot damage the tender leaves of the plants (July/August depending on inundation by rain or river water and rice growth). Typically the fingerlings will have attained 10 to 20 cm in size at stocking. In addition to the carp species stocked, freshwater prawn (*Macrobrachium rosenbergii*) and the high value carnivorous species *Lates calcarifer* are also stocked at Moyna.

At Moyna, chopped snail meat (locally harvested) was also provided as food for the prawn and carnivorous fishes. *L. calcarifer* fingerlings are stocked at this site both because of their high market value and to control the small wild fish and small prawns that breed freely in the waterbody and that can compete with the stocked carp for food and space.

During this period the renter retains labourers to manage and guard the fish ponds. These labourers are typically paid between 30 and 40 INR per day and are also provided with two free meals per day. The renter and the labourers undertake manuring, guarding, netting, sampling. They will also be involved in harvesting the fish when additional labour is often also involved (see also MRAG *et al.* 2003 for details).

In contrast to Moyna and Kamardanga there was no attempt made to keep fish between growing seasons and fish were instead stocked annually. Stocking occurs in June/July with locally sourced carp fingerlings of 10-15 cm. The local farmers provided the labour for guarding and harvesting during the culture period.

3.2.5 Management outcomes.

The outcomes of management will focus on the areas that were the focus of the learning strategy, i.e. rice cultivation, fish production and the benefits and distribution of benefits from management. A summary of the production from the three fresh water sites is given in Table 13.

Table 13 Summary of rice and fish production from the fresh water sites.

Site	Total area (ha)	Fish production (kg/ha)	Rice production (kg/ha)				
			Kalisankar	Jayacross	Bullet	Udaygiri	Swarna Masuri
Moyna	273	422.9-591.0	3075-3369	3281-3525	-----	------	-----
Kamardanga	110	279-875	-----	2250-3000	3375-3750	4000-4500	-----
Malandighi	8	610	-----	1800	------	------	3375

3.2.5.1 Rice yields

The rice varieties cultivated at the freshwater sites were *Jaya cross, Kalisankar, Bullet*, *Udaygiri* and *Swarna masuri*. These varieties are the ones that are traditionally grown at the sites. In terms of production, *Jaya cross* at Moyna (Dakshin changra chak, Gopal chak, Janaki chak, Mathuri chak, Baital chak and Charandas chak) performed well but this variety did not do well at the other sites where it was planted in experimental plots. At Kamardanga (Dhamar beel and Kamaner beel) performance of *Udaigiri* and *Bullet* were highly satisfactory giving production of 4000-4500 $kgha^{-1}$ and 3375-3750 $kgha^{-1}$ respectively. At Malandighi where *Swarna masuri* was the preferred variety, production ranged between 3375-3550 $kgha^{-1}$. The result was disappointing in that the *Jaya cross* variety had seemed to have a great deal of promise and the degree to which the production differed at Kamardanga and Malandighi was a bit surprising. However much of the poor performance appeared to be due to unfamiliarity with the variety. This was rectified through training with the farmers from Moyna, who were also able to discuss the benefits of planting *Jaya cross* with farmers from the other sites. The result of this was that the farmers from Kamardanga and Malandighi were keen to be involved in future trails of the *Jaya cross* variety that were to be facilitated by the State agriculture department.

While the Jaya cross variety did not do so well at the other sites, it showed why it is so promising at Moyna. At Moyna the selection of rice variety Jaya cross was very significant since it can grow normally with the rise of water level up to 1-1.9 m height. Even in 1 meter water depth this variety is comfortable and can yield 4-5 t/ ha. In addition the variety proved resistant to pests and, because it was ready for harvesting after 120 days, the stumps remaining after harvesting provided useful nutrients that contributed towards the productivity of the fisheries at the site.

3.2.5.2 Fish yields

Fish yield from the waterbodies that were participating in the study were considered satisfactory by those managing them. Fish yields from the six waterbodies in Moyna varied from 423 $kgha^{-1}$ (Baital Chak) to 591 $kgha^{-1}$ (Dakshin Changra Chak) with the vast majority of this being due to the stocked fish component of the production. Yield at Malandighi was slightly above the level at Moyna at 610 $kgha^{-1}$. This was considered a satisfactory result and represented an increase compared to the previous production at this site. The individual percentages of fish retrieval varied between 32 and 60 percent.

Fish productions obtained from Kamaranga were variable with Dhamar beel (875 $kgha^{-1}$) producing higher yields than Kamner beel (538 $kgha^{-1}$). Stocking densities were fairly similar in the two waterbodies (3405 and 3240 respectively) but the fact that there was some flooding at Kamner beel that led to some escapement of fish combined with the higher productivity measured in Dhama beel may account for the higher yields from Dhamar beel. Growth of carp in both waterbodies was considered highly satisfactory, especially the catla, silver carp, and common carp and the production of stocked fish was 740 $kgha^{-1}$ (Kamner beel) and 373 $kgha^{-1}$ (Dharmar beel).

3.2.5.3 Experimental results

For the rice experiments the trials were compromised by the need for more training in the handling and cultivation of the *Jaya cross* variety. However this was addressed and further trials are expected to take place. The results of the active stocking experiment at the freshwater sites were also compromised by the fact that the waterbodies at Kamardanga were not stocked in accordance with the experimental plan. Due to modelling beforehand the design of the experiment was robust enough so that, despite this, the experiment was able to confirm the hypothesis that stocking with high yielding species could provide increased yields and no loss of income for the farmers. Total yield was found to be significantly greater for the high yield treatment ($p<0.1$) and was negatively correlated with waterbody area. The relationship was described by the model:

$$TotalYield = 508.06 - 1.16 Area + 79.71 yieldstocked \qquad R^2 = 0.69$$

Where total yield is in $kgha^{-1}$, area in ha and yieldstocked provides the magnitude of the effect of stocking with the yield treatment in $kgha^{-1}$. This indicates that stocking with high yielding species can provide an increase in the region of 80 $kgha^{-1}$ over high value species at the densities used. One of the purposes of the experiment was to see if production of low cost fish, of benefit to the poor, could be increased at no cost to the fish producer. As mentioned, income was not significantly different between the two treatments. However both the waterbody area and 'yield' treatment did appear to provide a small positive effect and the relationship is described by:

$$Income = 24178 - 75.26 Area + 1923 yieldstocked \qquad R^2 = 0.41$$

Where Income is in Indian Rupees and area in hectares. This suggests that the managers would not be disadvantaged, and could potentially benefit financially, if waterbodies were stocked with high yielding species. There was also no significant ($p>0.1$) increase in the transport and harvesting costs due to the increased yields from stocking with high yielding species.

Looking at the wild fish yields from the waterbodies, it was found that the yield of wild fish varied from 5 $kgha^{-1}$ (Gopal Chak in Moyna) up to 150 $kgha^{-1}$ (Kamner beel at Kamardanga). The higher yields of wild fish from Kamner beel as opposed to Dhamar beel (135 $kgha^{-1}$) may have been due to wild fish entering the waterbody during the flooding event. The species composition in all the waterbodies was mainly small wild species (e.g. *Anabas testudineus* and *Puntius* sp.) though at Dhamar beel there was a significant contribution to the wild fish catch from snakehead (*Channa* sp.).

There was a considerable difference between the contribution of wild fish to the catch at the Moyna and Kamardanga sites (see Figures 18 and 19). While the sites do exhibit a number of differences, they are similar enough in their productivity and linkages to other waterbodies for it to be hypothesized that the difference in contribution of wild fish to the total yield is due in large part to the stocking of *L. calcarifer*. This effect was considered in more detail at the brackishwater sites (see Section 3.3.5).

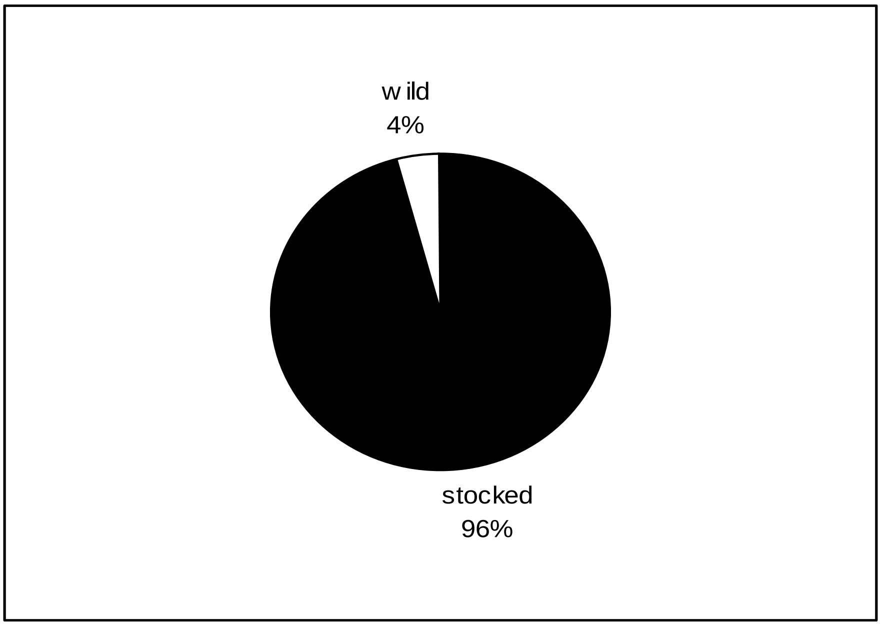


Figure 18 Mean catch composition from the waterbodies at Moyna.

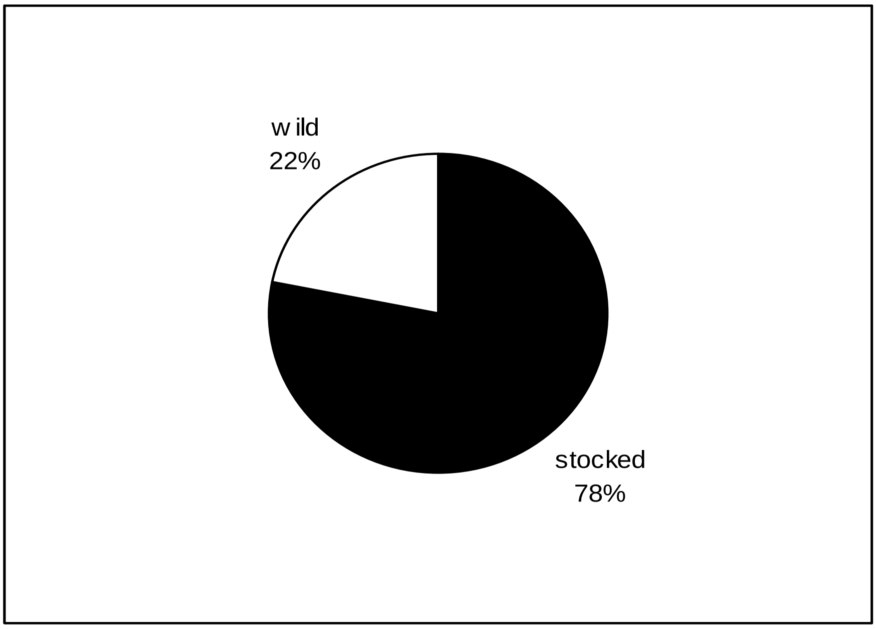


Figure 19 Mean catch composition from the waterbodies at Kamardanga.

While there was no significant difference ($p>0.1$) between the wild fish yields between the experimental treatments, yields of wild fish from Moyna did show a significant negative correlation ($p<0.05$) with waterbody area (Figure 20) with wild fish yield being explained by the relationship:

$$Wildfish = 45.05 - 0.517 Area \qquad R^2 = 0.68$$

Where wild fish yields are in kgha^{-1} and Area is in hectares.

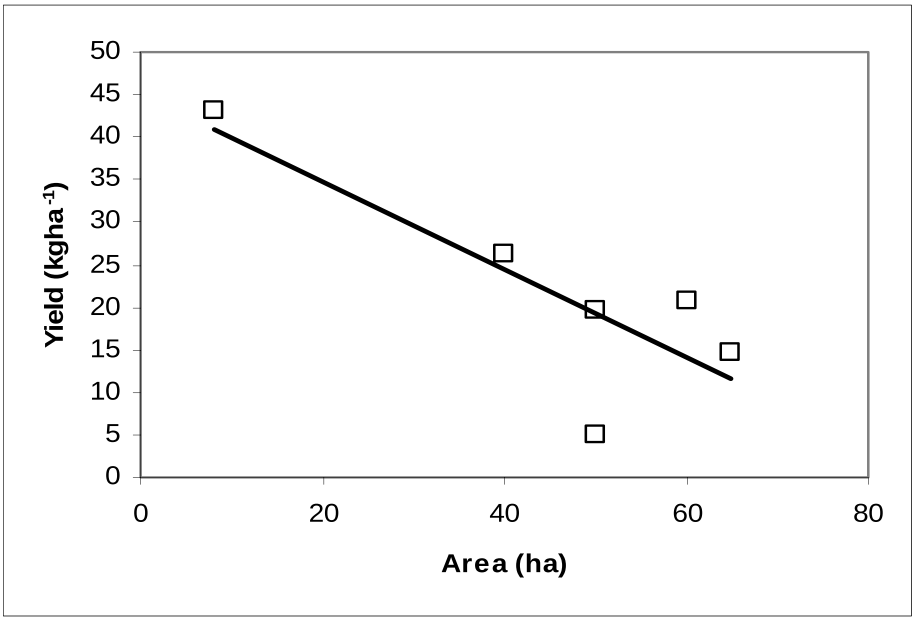


Figure 20 Relationship between wild fish yield and waterbody area for the waterbodies at Moyna.

The lack of a significant result in the experiment was due to a combination of compromising on the stocking treatments by including a larger, and therefore less informative, Indian major Carps component and the fact that the waterbodies at Kamardanga were not stocked in accordance with the experimental plan.

The opportunity had been taken to examine the management systems and the flows of benefits from managing the rice fish systems. This section describes the benefits that flow from the freshwater systems and who receives these benefits. At all the freshwater sites there are a variety of options for marketing the fish from the waterbody. At Kamardanga and Moyna the marketing options are constrained by the fact that in the first instance the renter is tied by the conditions of the loan agreement to supply a certain value of fish to the wholesaler from whom he took the loan needed to rent the waterbody. Beyond this, the renter may sell fish to local consumers who purchase directly (this accounts for only a very small amount of fish), local wholesalers, wholesalers in market towns or direct to the retailers at the market (Figure 21).

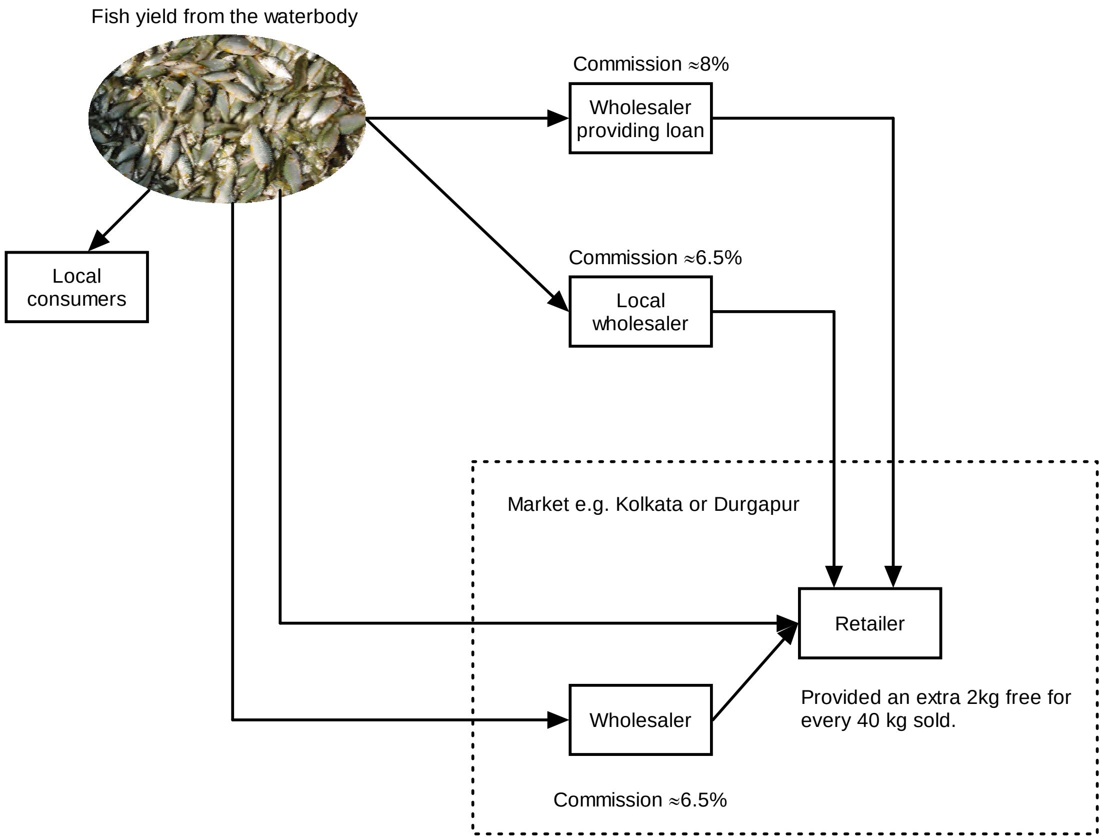


Figure 21 Marketing of fish from the freshwater sites at Moyna and Kamardanga.

As mentioned, the sale of fish to local consumers makes up only a very small proportion of fish sold. It is only in the case where someone is having a special occasion that the renter would be approached to supply fish. By far the majority of fish is sold through wholesalers, mainly local. The renter keeps a close eye on the fish prices in a range of markets, including the local wholesale market, and this influences the decision as to where to sell fish. While selling locally to a wholesaler will bring a lower price (Table 14), the transaction is simpler, less costly, and carries less risk. In some cases however an attractive opportunity has been identified by a renter outside the local wholesale market and the renter has hired a truck to transport the fish on ice for sale to a wholesaler in the market town and/or direct to the market retailer. In the case of the former, a commission is payable – as with the local wholesalers. In the case of sale direct to a retailer, the renter is paid by weight but the retailer will expect to receive two kilograms of fish free for every 40 kilograms sold. This is to compensate for any water and ice that might be in with the fish. Transporting and selling fish themselves is a more risky option for the renter as fish is a perishable product. This fact also makes the transport of fish vulnerable to groups who may detain the trucks until a payment is made. The detention of trucks was considered by the renters to be a major disincentive to marketing the fish themselves.

Table 14 Relative prices obtained for freshwater fish marketed in different ways.

Market	Price obtained ($INRkg^{-1}$)
Tied wholesaler*	30-35
Local wholesaler	30-35
Market wholesaler	35
Market retailer	40

*This is the wholesaler from whom the renter obtained the loan.

At Malandighi the NGO involved did not take out a loan and so was not tied to a particular wholesaler. The selling of the harvest did however follow a similar pattern with fish being transported and sold to a local wholesaler who then sold the fish on.

As mentioned in Section 3.2.4, at Moyna and Kamardanga while most of the catch is sold at the time of harvest, some of the smaller stocked fish are kept back in smaller ponds (0.6-0.9 metres deep) within the waterbodies. Some of these fish are sold during the year while the others are retained to be sold to the renter the following year.

Analysis of the management systems in the freshwater sites indicated that there were a range of benefits and beneficiaries associated with the resource systems. In addition to the renter, wholesaler and labourers, who all benefit directly from the fishery, there are additional beneficiaries including some of the poorer local households, the landowners associated with the site and also the wider village community at the site. The types of benefits each of these receives is shown in Figure 22. The three categories of benefits identified by Garaway (1999) were to determine the benefits from the system and to show how fish and rice yields from the system translated into benefits for the various recipients. In the first place, fish from the waterbody provided a nutritional benefit not only to those who purchased the fish from the market retailers and consumed it. Fish was also provided to those involved in harvesting it and, in the case of Dharmar and Kamner beels, to those guarding the waterbody. After fish has been harvested, a number of poor households (up to about 20-30) are allowed to harvest the smaller wild fish and prawn. They are able to take up to two or three kilograms which they utilise primarily for household consumption, although some may also be sold.

As can be seen from Figure 22, the main financial beneficiaries from the management are the renter and the wholesaler from whom the renter received the loan. The landowners and the wider village community also benefit from the system both directly and indirectly. A direct benefit to the wider community is that following harvesting, poorer households are allowed to collect wild fish and other aquatic organisms for household consumption and sale. Indirect benefits are received through the use of the lease payment by the village development committee. This money, held in a village development fund, is used to provide a range of benefits including investment for the benefit of the site landowners such as the tilling of the soil, dyke maintenance and irrigation systems. The wider community benefit from the use of funds by the committee through spending on development activities such as the school, temple or road improvements, contributions towards the village festival and direct payments to households in need.

In contrast with this system of management, the benefits from the privately (NGO) managed waterbody at Malandighi are shown in Figure 23. Under this arrangement the NGO provides the land and water resources and advances the inputs. People from the local village supply their labour for which they are rewarded with 50% of the profits from the rice cultivation and the fish culture. At the same time, these people are also benefiting from fish and rice that are provided as reward at the time of harvest. Other poor people who were not involved in the culture and cultivation are allowed to take small quantities of wild fish at the time of harvest. During the dry season the land is fallow and the local villagers are allowed to use the waterbody for limited subsistence fishing. In comparison with the leased system, the benefits from this arrangement are much more direct. The villagers supplying labour appeared to be satisfied with the arrangement as they are able to provide their basic household food requirement and do not run the risk of becoming victim to exploitation by money lenders as they would not be able to afford to be involved in rice cultivation and fish culture without some source of credit.

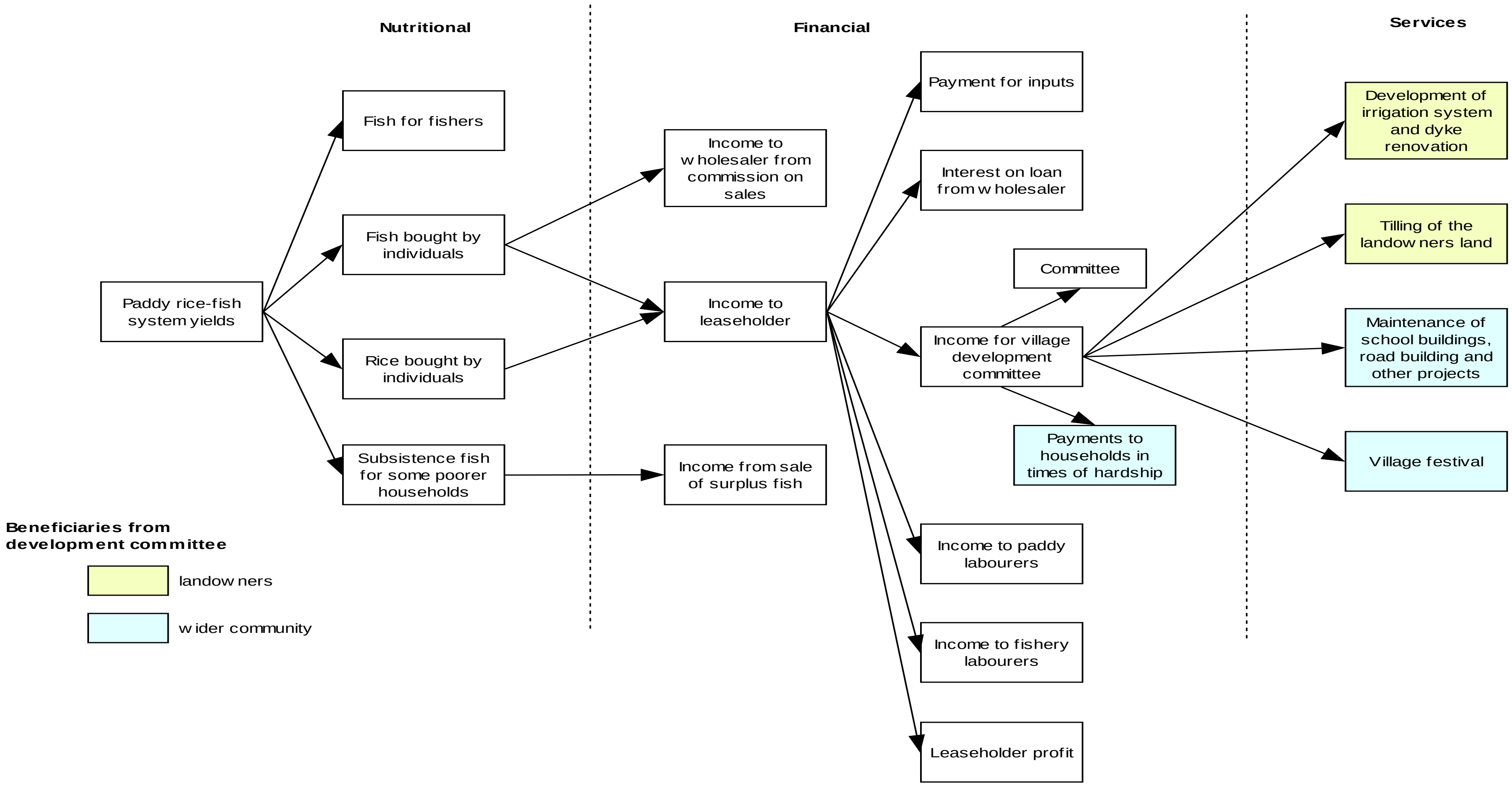


Figure 22 The distribution the different benefits from the lease system of management used at Moyna and Kamardanga.

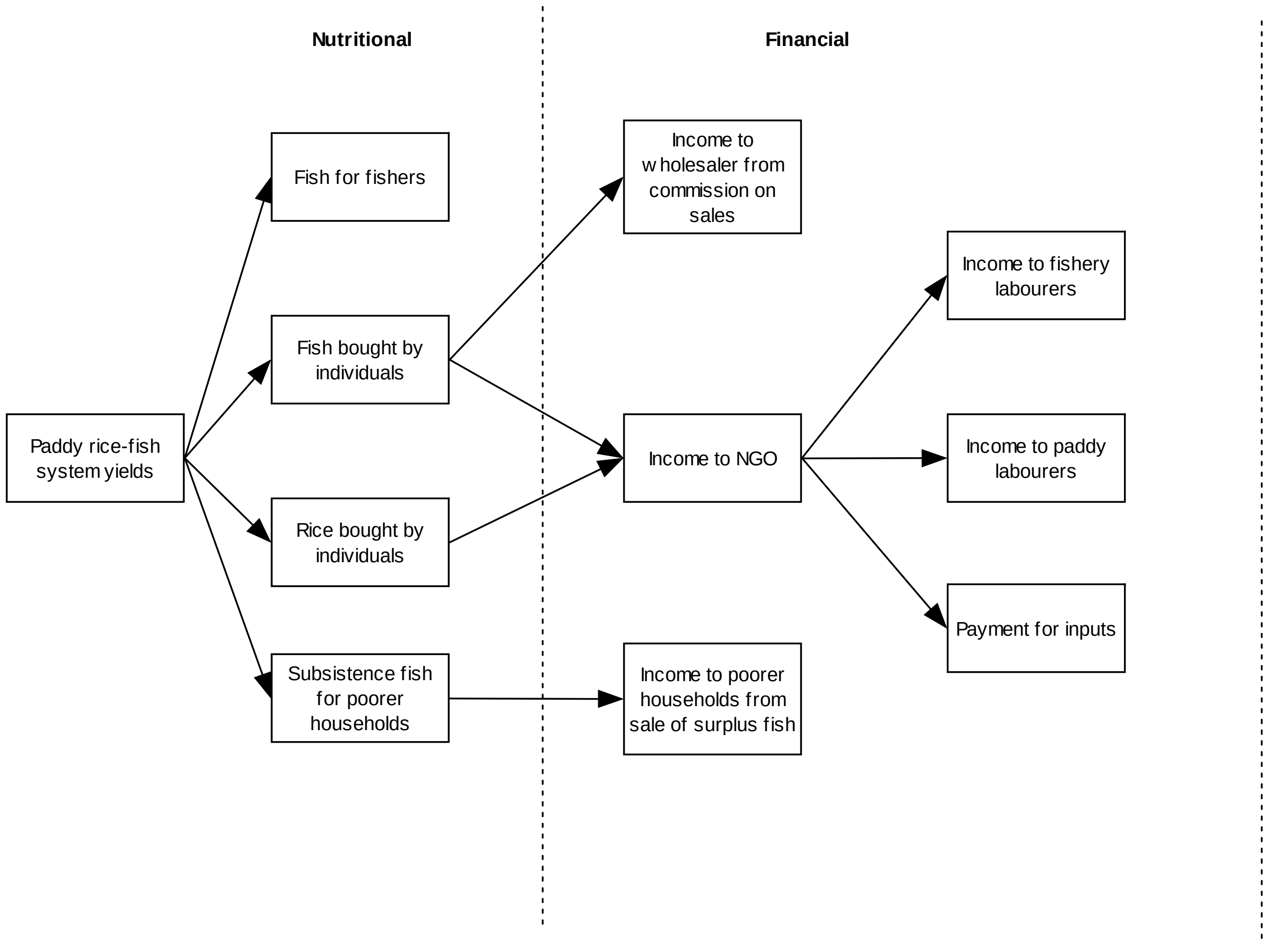


Figure 23 The distribution the different benefits from the private system of management used at the freshwater site at Malandighi.

The particular benefits to the landowners and wider village community from the management systems at the freshwater sites are shown in Table 15. As can be seen the range of indirect benefits from the leased operation (provided via the village development fund) were much greater than from the privately managed waterbody. The operation of the village development committee differed also between Moyna and Kamardanga. At Moyna the landowners received particular benefits in the form of land preparation and irrigation paid via the fund wheras at Kamardanga the benefits were all shared across the whole community with no additional benefits for the landowners.

Table 15 Benefits received by farmers and villagers at the three freshwater sites.

Beneficiary	Moyna	Kamardanga	Malandighi
Landowner	Benefits from employment in culture operations. Benefits from rice cultivation. From development fund: Tilling of plots using power tiller, repair of dykes and dry season irrigation. In times of drought or flood each landowner receives INR 1500-2000 from the development fund.	Benefits from employment in culture operations. Benefits from rice cultivation.	Income from cultivation and culture operations.
Villager	Employment in culture operations. Access to wild fish by poorer families. From development fund: Repair and maintenance of school buildings, road construction, schooling costs for poorer families, contributions towards marriages and funerals, digging of wells, contribution towards village festivals.	Employment in culture operations. Access to wild fish by poorer families. From development fund: Road construction, repair and maintenance of school buildings, construction of health centre, provision of midday meal for school children, polio vaccination programme, contribution to village festivals, donation to temple, funding of local youth theatre group, contribution towards costs of local sportsmen, towards marriages and funerals.	Benefits from employment in cultivation and culture operations.

In terms of management constraints, farmers at Moyna and Kamardanga rated financial constraints as a major constraint to management. It was assumed that if alternative sources of funding could be developed then the dependency of those renting the waterbodies on financing from the wholesalers (and the conditions that accompany these loans) would be lessened. The difficulty faced by the renter is that they do not have ownership of the land as they are only leasing the fishery option and so cannot obtain loans from the banks. However, it is unlikely that the renter would take out a loan from a bank to finance the operation even if they could. This result was in the first instance surprising as it seemed that this option could help reduce the financial constraints. However the renters were highly risk averse and would secure loans from wholesalers even when they could have financed the operation from their own resources. By taking a loan, the risk was with the wholesaler and, should the operation make a loss over the year, the renter would generally be given the opportunity to recoup the loss in the following year. This would not have been possible with a bank loan where the risk to the renters' assets would have been much greater. Thus while the loan was not so attractive in terms of the returns, the loans were quite flexible and low risk.

3.3 Brackishwater systems

The brackishwater site at Tangramary village was in North 24 Parganas district (Figure 1). Tangramary is a village of 108 households (average household size is five people) situated on the bank of the Ichamatti river about 5km from Hasnabad town. The people in the village have livelihoods that are heavily dependent on aquatic resources (see Figure 24) with some 56.5% villagers having fish culture as primary occupation. About 200 men from the village work as fishers, working on the Raimangal, Jheela, Bidyadhari and Icchamati rivers and in areas of the Sunderbans. These fishers operate a range of gears including drift net, gill net, cast net, drag net and hook and line. This fishery operates from May through to January/February and fishers can expect to earn in the region of 700-750 INR per month as well as receiving free food. Women and children in the village also fish, collecting a range of aquatic organisms including fish, crabs, shrimp and snails from the nearby rivers and streams using gears such as drag nets and scoop nets. The women and children also collect shrimp seed for sale locally and in the Hasnabad seed market.

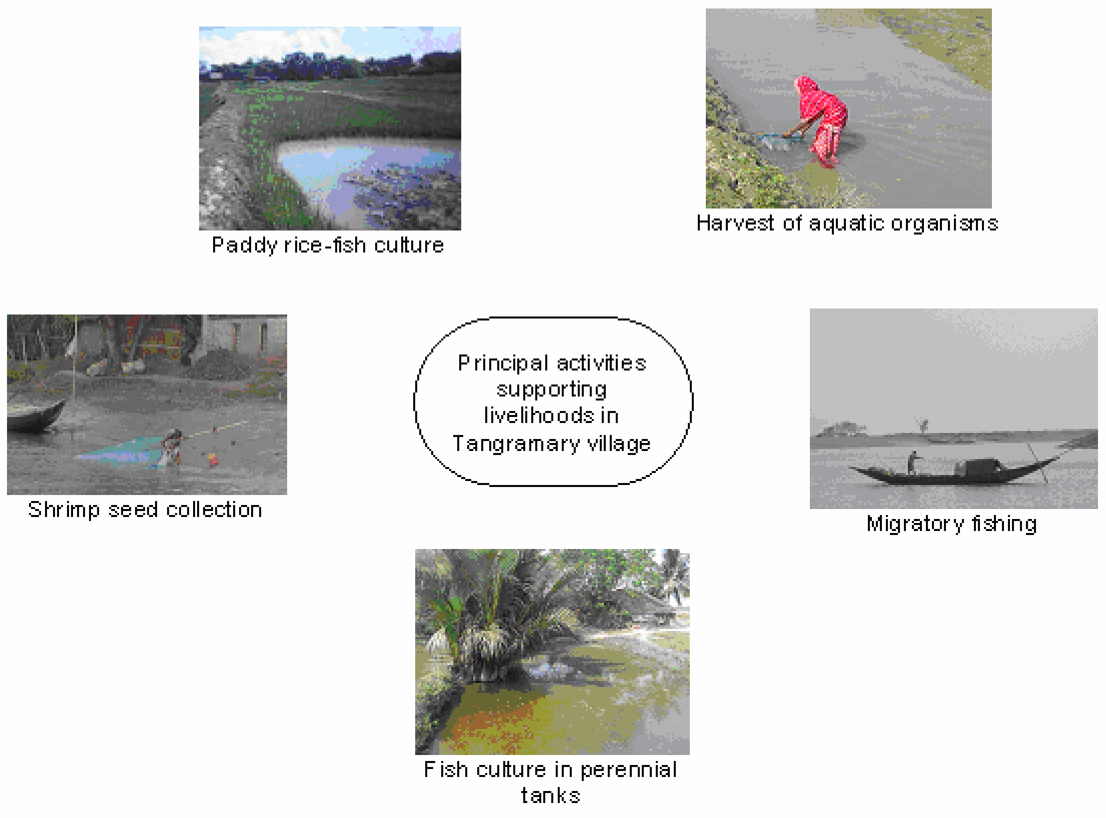


Figure 24 Principal household activities in Tangramary village*.*

The rice fish culture activities occur year round as the systems generate two crops of fish and one of (wet season) rice (see Figure 25). The waterbodies used for rice-fish culture are small (0.25-0.75 ha) *bheris* that were situated on the bank of the Dansa river. This places the *bheris* between the river and the main irrigation embankment. As such, this means that the land actually belongs to the government and therefore that the village does not receive any official support from the Panchayat or government agencies for the development of this land. The main objective of the households managing these systems is to maximise household income at relatively low risk and also provide some fish and rice for household consumption.

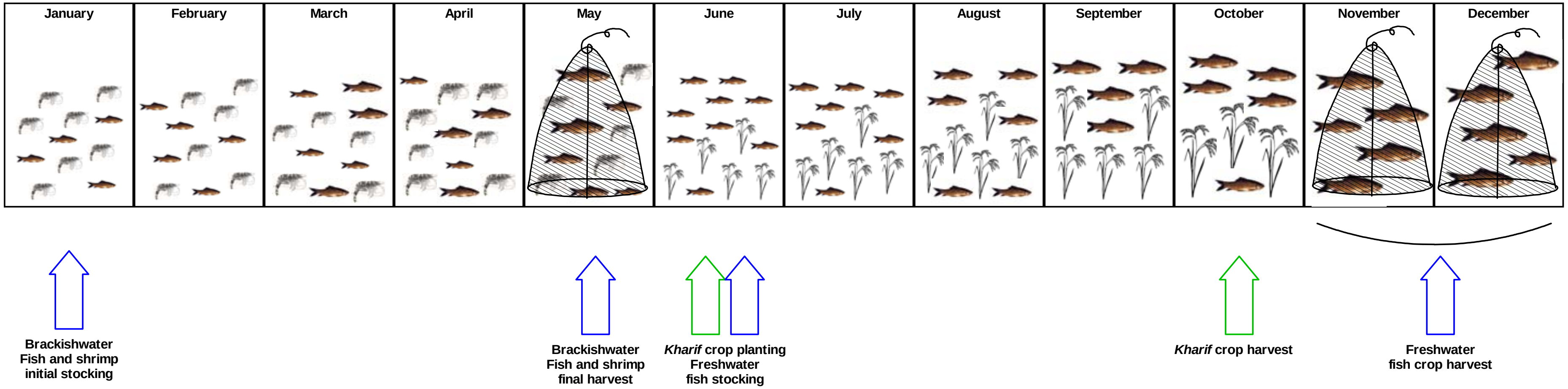


Figure 25 Seasonal calendar depicting the process of fish culture and rice cultivation at the site at Tangramari.

3.3.1 Biophysical characteristics

The biophysical site characteristics differed substantially from the freshwater areas in a number of ways. Not only were the waterbodies far smaller but the majority were directly connected with the river, which was subject to tidal , which was subject to considerable annual fluctuations in both water temperature and salinity. The range of aquatic organisms in the area were also different in many ways to those found at the freshwater sites.

The soil composition in the coastal areas such as Tangramari is mostly of a clay nature, having a high silt content (Table 16). The high silt content means that while the soil will harden on drying it is also very prone to erosion if subject to water flow. This means that dykes and embankments built using this soil have to be tended to ensure that the construction is not washed away. When wet, the soil is also vulnerable to burrowing organisms such as eels and crabs. The other parameters were considered to be conducive for growing rice and for fish culture and the C/N ratio of 10.2 indicates that there should be a conducive environment for the growth of benthos.

Table 16 Sediment Soil characteristics of Tangramari

pH	Conductivity (mmhoscm^{-1})	Total N	Available Nitrogen	Available Phosphorous	Available Organic carbon	Mean C/N	Mean Sand (%)	Mean Silt (%)	Mean Clay (%)
8.3	2.02	0.06	11.5	3.8	0.48	8.0	42	44	14.0

The water quality in the waterbodies at the brackishwater site depended largely on the exchange of water with the river channel and was subject to changes in the characteristics of the river water. Water depth was maintained at one metre throughout the dry season fish culture period through fortnightly water exchange, providing suitable conditions for culturing brackishwater fish and shrimp (Figure 26). As can be seen, the water depth followed the rainfall pattern for the location (Figure 5). Water temperature in the waterbodies increased during the dry season and decreased during the wet season.

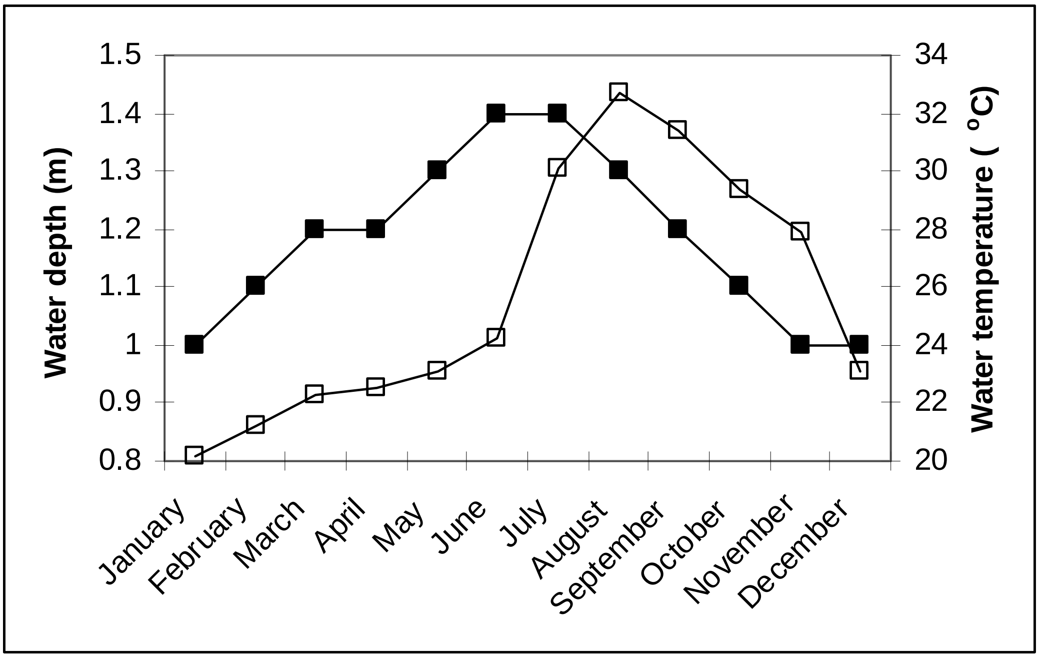


Figure 26 Variation in mean water depth (■) and mean water temperature (□) in the waterbodies at Tangramari during 2004

The resource systems at the site are subject to fluctuations in salinity that are driven by the monsoon rainfall (Figure 27). As can be seen, the salinity is gradually increasing through the dry season when there is lower flow in the river and hence the water is more saline. The onset of thee monsoon rains brings about a rapid decrease in salinity to less than four parts per thousand (ppt), a level that is maintained through the wet season. Nutrient values of the water were observed to be favourable for good fish/shrimp production and the pH of the systems varied between 7.1 and 7.9.

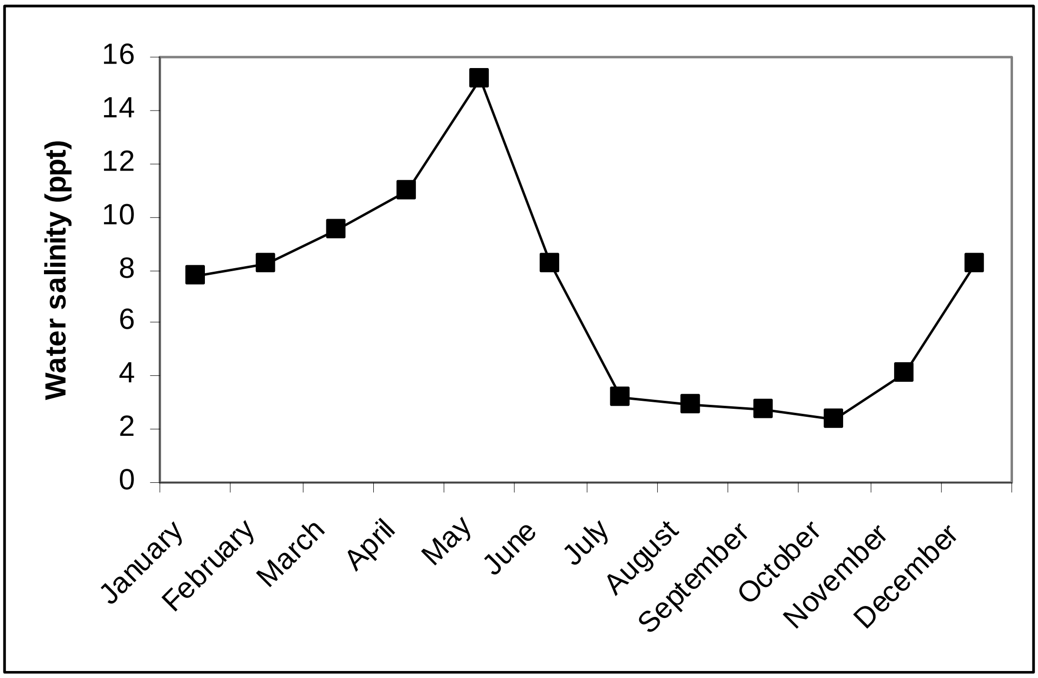


Figure 27 Variation in mean water salinity in the waterbodies at Tangramary during 2004.

Plankton and algal structure:

The brackishwater environment is a complex one in terms of survival and growth of plankton and algal flora because of the salinity changes, tidal influence, current velocity and varying tidal regime. As the tides are always moving in and out, attached algae have to cope with an environment that ranges from total inundation to complete exposure to sunlight. The salinity regime across the different seasons together with the changes in current velocity and tides are also responsible for the growth and survival of algae and plankton and changes in abundance and distribution over time. Table 17 indicates the relative seasonal abundance of various types of algae and plankton. The fish and shrimp production depends for a large part on availability of such plankton production.

Table 17 Plankton structure in the bheries at Tangramary

Species	June – Sept	Oct – Jan	Feb – May
Chlorella sp.	----	++++	+++
Enteromorpha sp.	+++	++	+++
Ulva sp.	----	+++	++
Chaetomorpha sp.	+++	+++	++
Lola sp.	----	-----	----
Spirogyra sp.	++++	-----	-----
Oscillatoria sp.	++	+	-----
Cosmenium sp.	+++	++	+
Phoridium sp.	++	+++	+
Scytonema sp.	+	++	++
Nitzschia	++	+++	++

+ less,++ moderate +++ more

3.3.2 Management

The 38 *bheris* included in this study varied in size from two bigha (0.29 ha) up to four bigha (0.52 ha). The *bheri* is used for both rice and fish culture throughout the year. The *bheris* are fed by water from the river that enters the waterbody during high tides. To enable the exchange of water, during the spring tide period the dyke separating the *bheris* from the river is cut. At this time a *patta*, small mesh netting or bamboo screen, is placed across the gap to prevent fish and prawns from escaping and predators entering. To enhance fish and shrimp production, channels and nursery pits are dug in the paddy fields that provide additional habitat for the fish and shrimp (see Plate 3).

Plate 3 Low lying parts of the waterbodies in Tangramary village include a pit dug for nursing shrimp and prawn seed (left) and ditch along the edge of the waterbody (right) (Photos: R. Arthur).

Rice-fish culture begins with the start of fish culture in January. Following a short, one month, fallow period saline tidal water is allowed into the waterbody during the spring tide period to fill the low-lying parts of the waterbody (Plate 3) and post larvae of a variety of aquatic organisms including crabs, prawn (e.g. *P. monodon* and *P.indicus*) and fish (e.g. *Lates calcarifer*, *Liza* sp.) also enter at this time. Larger fish entering the waterbody are caught in traps and removed for sale or consumption. During this period lime is applied after soaking for 24 hours and then 15 days later superphosphate is applied and sometimes also cow dung or oil cake to raise the fertility of the water (see also Table 18).

Table 18 Typical fertilizer inputs and costs in rice fish culture at Tangramari.

Input	Rate typically applied (kgha^{-1})	Cost (INRkg^{-1})
Lime	200	5
Superphosphate	200	5.5
Urea	50	5
26:26:10 (NPK)	100	5

In addition to the natural stocking of the waterbody, shrimp and prawn seed (*P. monodon*, *M. rosenbergii*) are stocked together with fish seed including *L. calcarifer*, *Liza parsia*, *Liza tade* and *Mystus gulio*. These seed are collected from the wild and additional seed are purchased from local traders and/or the seed market in Hasnabad. Stocking densities are variable but typically quite high (see also MRAG et al. 2003). The amount stocked and final species mix depends upon availability of seed and financial resources, a not uncommon situation (e.g. Arthur 2004, Nguyen *et al*. 2001).

During the culture period there is a regular intake of water during the spring tides and feeding with locally made feed. This feed is made from a range of locally available ingredients including rice bran, wheat flour, fish meal and oil cake in various proportions (Table 19). These proportions, and the frequency of feed application, are both dependent on the experience of the farmer and availability of ingredients and finance. The ingredients are combined with some water to form a moist dough. This dough is then formed into small balls that are allowed to semi-dry before being thrown into the waterbody at four to five different points. The farmers check the growth during the culture period and may adjust the feed recipe and feeding rate depending upon results.

Table 19 Typical ingredients in feed applied in Tangramary.

Ingredient	**Typical proportion (%)***	**Approximate cost (INRkg^{-1})**
Rice bran		1.5-2.0
Groundnut oil cake		8
Mustard oil cake		6
Fish meal		15 – 25
Soya bean flour		30.0
Broken rice (*chira*)		8.0
Wheat flour		6 – 8
Maize flour		5 – 8
Boiled potato		2 – 3
Dead fish/shrimp mixed with turmeric powder		5 – 8

*note that not all ingredients would necessarily be included.

The brackish water species are partially harvested and some stocking occurs every two weeks up to the end of the brackish culture period when the monsoon rains arrive (June/July). Harvesting also yields wild fish (e.g. *Myatus gulio, Pangasius pangasius, Plotosus canius, Therapon jurbua, Xenenthodon sp., Sillago panijus, Scatophagus argus, Gobids,* etc). and shrimp (including *Metapenaeus monocerus, M. brevicornis, Parapenaeopsis sculptis*) that are also sold or, in the case of lower value species and crabs, taken for household consumption. In a number of cases the shrimp have been affected by viral disease and in response to an outbreak, farmers would apply neem oil cake at 50-70 kgha^{-1} followed by $KMNO_4$ at 1-2 kgha^{-1} in order to check the spread of the disease. If the outbreak was severe the farmer would drain the pond, harvest what was there and then apply lime and dry the pond for about a month before restocking.

Following the brackishwater culture period (Figure 25), there is a second, freshwater culture period for which there is an essentially single stocking event in June/July. This coincides with the monsoon when the salinity decreases and the rice crop is transplanted. The runoff from the monsoon rains lowers the salinity in the river from which the water is drawn. This low salinity water is allowed during the spring tide period to fill the whole waterbody. At this time a number of freshwater species including the Indian major carps (a mix of *C. catla, C. mrigala and L. rohita*), silver carp, bata, punti and larger sized tilapia (*O. mossambicus*) are stocked, usually at fairly low densities. Tilapia are well suited for rice fish systems as they are fast growing and problems of overpopulation and stunting that are reported from culture in perennial waterbodies cannot occur as the paddy fields are dry between rice crops. However the Indian government is opposed to their introduction.

Rice culture in these plots starts prior to the arrival of the monsoon rains. In May/June the paddy rice seeds are germinated in separate seed beds that are away from the culture plots. The usual practice is for farmers to buy seedlings from those who have seed beds after one month or so and these seedlings are transplanted, with the assistance of hired labour, after the rains have arrived lowering the salinity in the waterbody. At the time of transplanting, urea at about $kgha^{-1}$ is applied. A second application of urea at a similar dose rate or lower is made just prior to the flowering stage if required. The rice plants are closely monitored and if it is felt that the number of tillers are low then fertilisation with cow dung (1000-2000 $kgha^{-1}$) and/or mixed NPK and superphosphate fertilisers (200-300 $kgha^{-1}$) are applied. The paddy rice matures after about 100-120 days and is harvested, again with the assistance of paid labour. These labourers are hired to help with transplanting, weeding, harvesting and threshing of the rice.

The landowner and family share management responsibility and regularly check the condition of the dyke, making repairs as necessary. In addition they watch over the waterbody, using torches at night, to prevent illegal fishing. For times where there is a need for additional labour, for example for paddy rice transplanting, paddy rice harvesting, dyke repair and fish harvesting local labourers are engaged. These labourers would receive payment of INR50 per day as a standard rate but might get INR30 per hour if there was an emergency that required immediate labour. During fish harvesting, in addition to payment of INR50 per day, fishers would also each receive between 0.35 and 0.75kg of fish, depending upon the amount caught. Overall, for rice culture the labourers would be engaged for between three and five days in total. For fish culture the labour employed in the freshwater sites could be either owned or renter or landless catagory.

3.3.3 Rice production

Three salinity tolerant rice varieties were cultivated at Tangramari during the study period (Table 20). Of these, CSR1010 was the variety introduced as an experiment on advice from local extension staff and discussion with farmers. As the table shows, the maximum production was obtained with Bangladesh Patnai and IT 5656. Unfortunately CSR1010 showed a poor performance in terms of both growth and yield at the site and farmers expressed their decision to continue to use Bangladesh Patnai in the rice- fish production systems.

Table 20 Rice production at Tangramari

Group	Rice variety		
	Bangladesh Patnai (kg/ha)	CSR 1010 (kg/ha)	IT 5656 (kg/ha)
I	1000-1750	200-240.3	
II	900-2400	300-875	625-1750
III	1600-2307	325.6-576.9	800-1650
IV	1540-2250	375-675	950-1600

3.3.4 Fish and shrimp production

Total fish and shrimp production is a combination of the yields from both the brackish production cycle and the freshwater production cycle. These will be examined separately.

The production of fish and shrimp from the brackish period of the culture cycle, the production was dependent upon both stocking and the recruitment of wild fish and prawns from the river. The range of inputs and outputs are shown in Table 21.

Table 21 Ranges of inputs and outputs from the brackishwater fish culture component of the culture cycle at Tangramari

Component	Maximum	Minimum
Inputs (nha^{-1})		
L. calcarifer	3846	0
M. rosenbergii	9615	1071
P. monodon	38461	11538
Other stocked finfish*	19592	5432
Outputs (kgha^{-1})		
L. calcarifer	11.54	0
M. rosenbergii	30.77	5.77
P. monodon	33.08	11.54
Other stocked finfish*	43.46	6.15
Total wild shrimp and fish	55.77	12.31
Total yield	109.23	52.79

* includes M. gulio, Liza sp. and O. mossambicus

The composition of the seed inputs into the fish ponds are shown in Figure 28, while Figure 29 shows the composition of the catches.

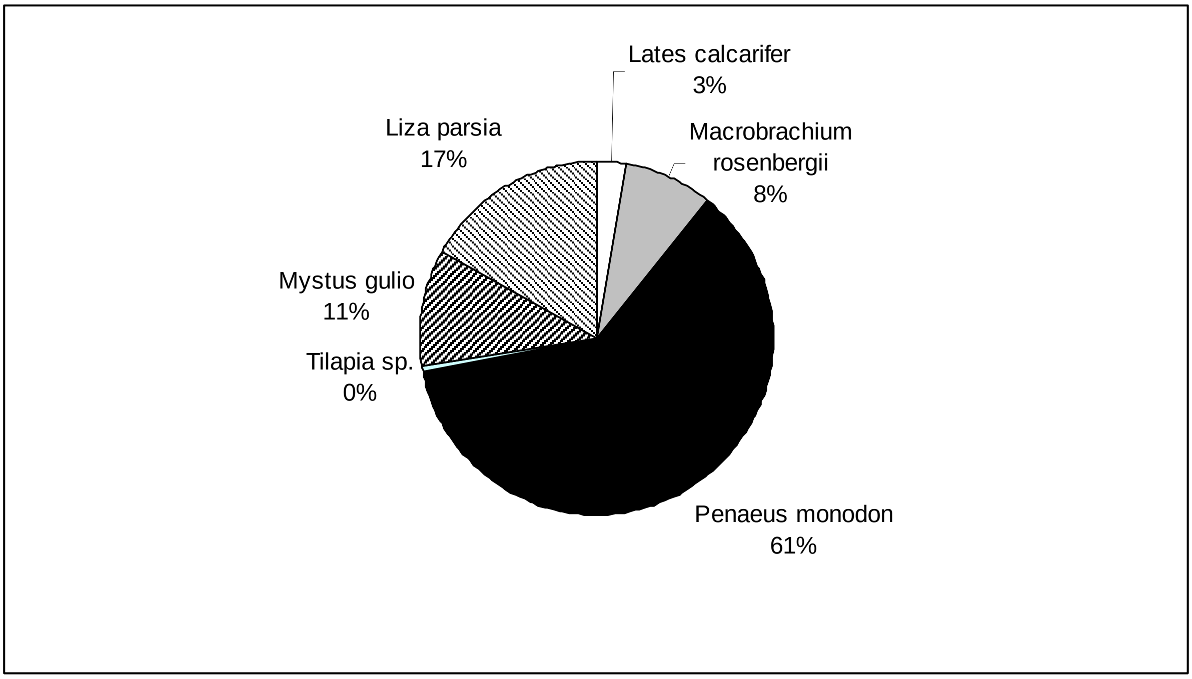


Figure 28 Mean percentage contribution in number per hectare by species to total seed inputs in the waterbodies during the brackish culture period.

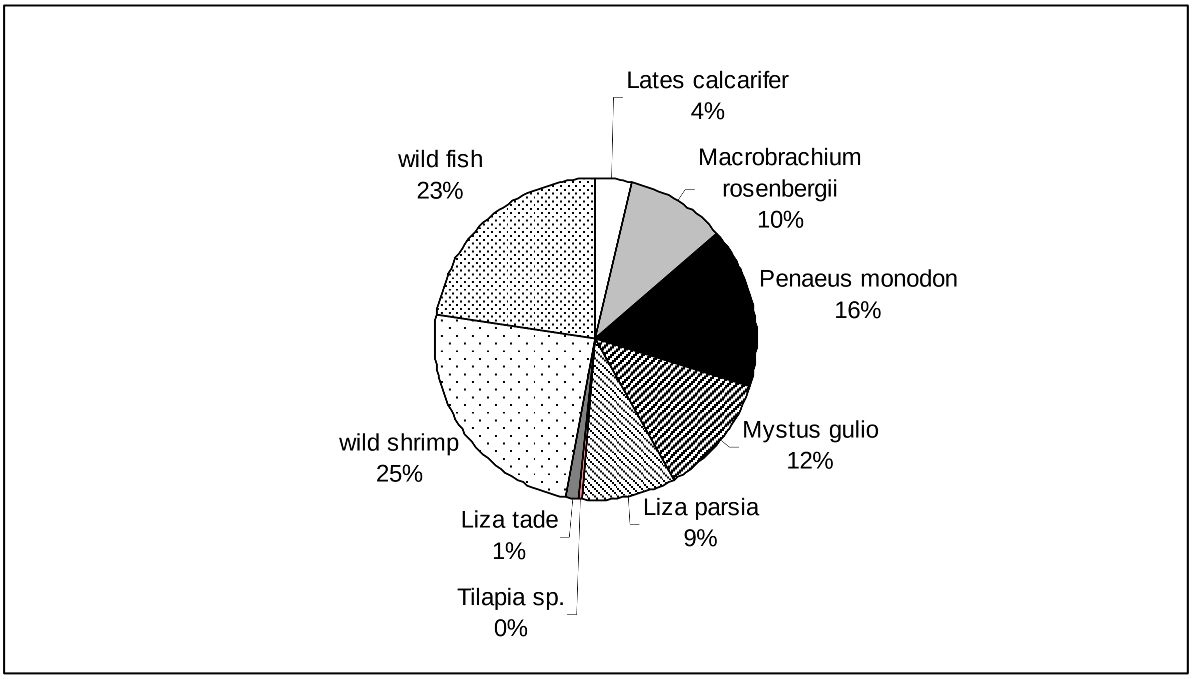


Figure 29 Mean percentage contribution in kilograms per hectare by species to the total yields from the waterbodies during the brackish culture period.

As can be seen, wild fish and shrimp make an important contribution to the total yield from the waterbodies during the brackish culture period and the contribution of the wild species to yields was greater than for the freshwater culture sites. This contribution is examined in more detail in the description of the experimental results (see Section 3.3.5). As can be seen from Figures 28 and 29, the relative contribution to outputs and inputs was not the same for the different species. Given that there were a range of species stocked it is interesting to examine the returns from the stocking in terms of the yield per seed fish for each of the species (Figure 30). This shows that the best shellfish returns from growth were from *M. rosenbergii*. In fact this had the best return of all the species while *P. monodon* provided the poorest returns. Of the finfish, *L. calcarifer* provided good returns, as did *M. gulio*. Tilapia were expected to give returns as this is an omnivorous fish that is very popular with farmers because of its hardiness and good growth. However the results indicated that, of the finfish species stocked, tilapia gave the poorest yields per fish stocked. The most probable reason for this is that the results are based on low reported stocking numbers (See Figure 28) and little data available) although it may be that tilapia perform less well in the brackish environment and would be expected to give better returns during the post-monsoon freshwater culture period.

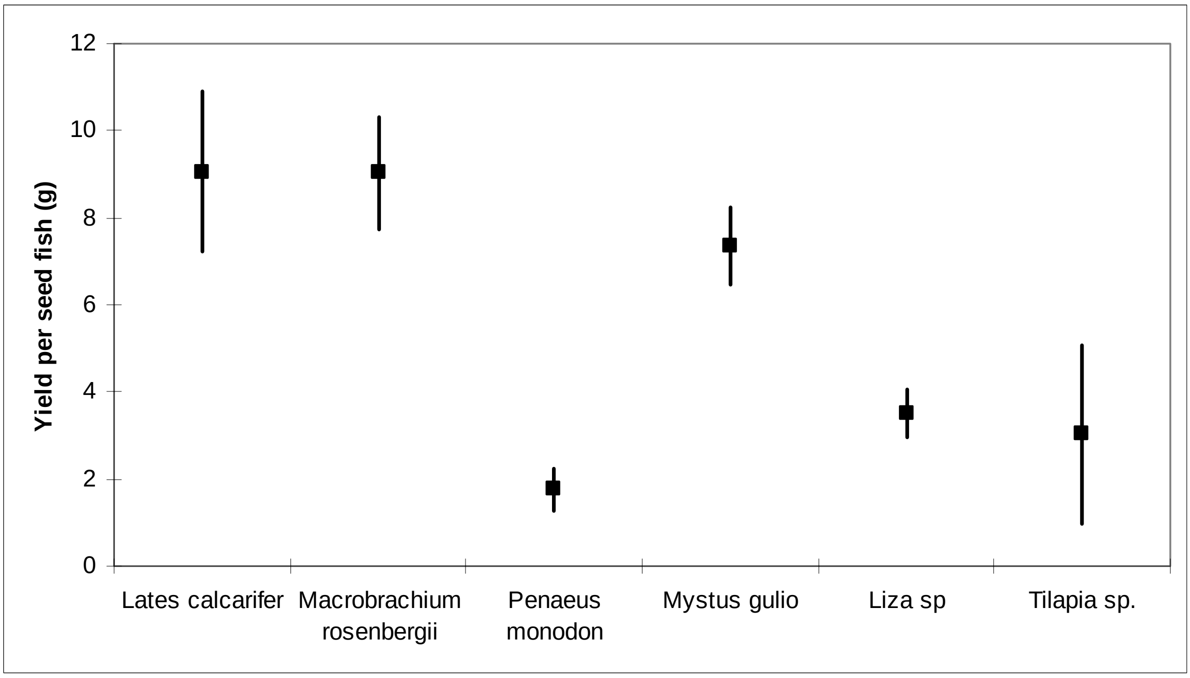


Figure 30 Mean yield per seed fish during the brackish culture period. Bars indicate 95% confidence intervals.

Table 22 Typical size at harvest and prices obtained for brackish water shrimp and fish during the study.

Species	Size at harvest (g)	Price obtained (INRkg^{-1})
P. monodon	30 - 50	250-350*
Mullet (*L. parsia* and *L. tades*)	50 - 350	50-70
L. calcarifer	250 - 400	50-60
M. gulio		30-40
Catla	400 - 600	40-42
Rohu	300 - 350	40-42
Mrigal	300 - 400	40-42
Silver carp	200 - 400	35-40
Punti	100-150	40-45
Tilapia	50+	35-50
Miscellaneous wild fish	10+	25-35
Miscellaneous wild prawn	15-25	25-50

*based on an average of between 20-40 individuals per kilogram.

The financial returns from stocking (Figure 31) are also interesting. The results show that P. monodon clearly provides the poorest overall returns to investment. This is a species with a high market price and consistent demand and so it can provide good returns when growth is good and mortality rates are low. However, it is relatively expensive to stock (400 INR per thousand compared to 100 INR per thousand for *M. gulio* and *Liza* sp.) and there is a constant risk of disease with this species that means that culture has to be stopped and the pond dried with resultant loss of production (25% of farmers in the study were affected by disease outbreaks in *P. monodon*). The cost of stocking and disease outbreaks have contributed to the low returns from this species. Of the finfish species stocked, L. calcarifer gave good returns because of its high market price and good growth while tilapia and mullet (*Liza* sp.) did less well.

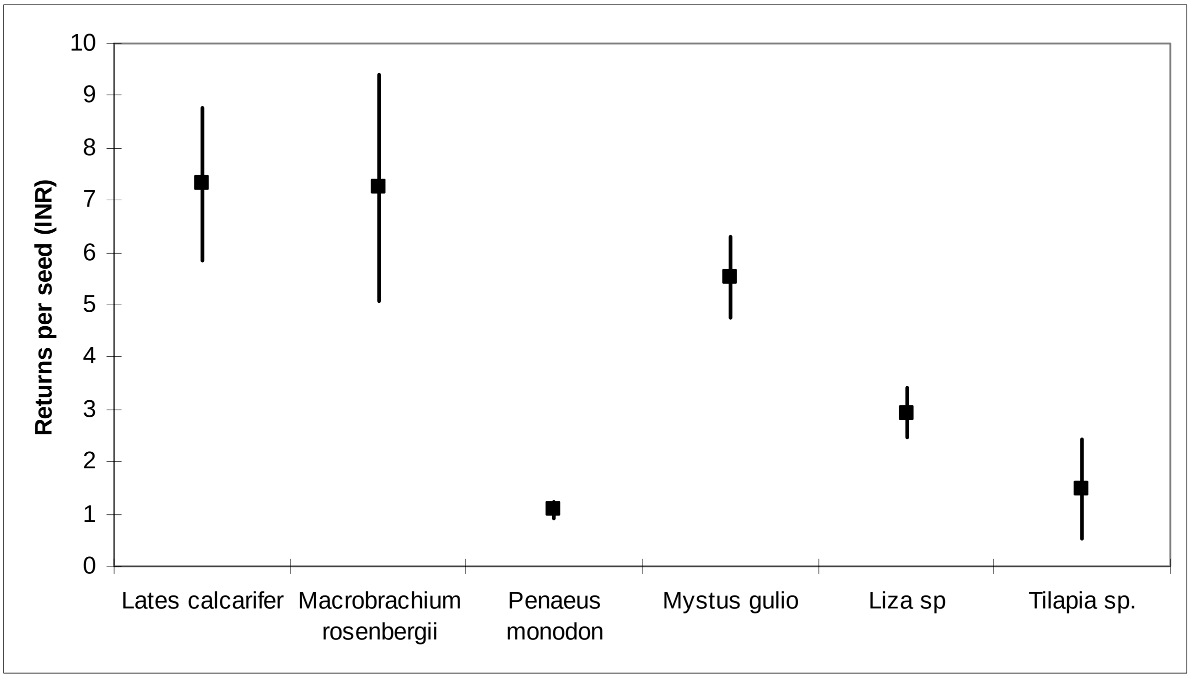


Figure 31 Mean financial return on investment per seed fish. Bars indicate 95% confidence intervals.

Given the good returns from *M. rosenbergii* in terms of both yields and income, it might be expected that farmers would seek to increase the stocking of this species at the expense of *P. monodon*. However, *M. rosenbergii* exhibits cannibalistic behavior and this behavior limits the amount of seed that can be stocked. To avoid the cannibalism, and also to protect shrimp during moulting from predation, the farmer places tiles, pipes and other materials that will provide a refuge in the waterbody.

3.3.5 Experimental results

The experiment was conducted across 37 plots (one was discarded during the analysis as the data was not collected consistently during the study period.

3.3.5.1 Brackish period.

As described in Section 2.3.3, the experiment was designed to see whether changes in management practices, i.e. not stocking bhetki (*L. calcarifer*) and providing a dried pelleted version of the farmers feed rather than moist, could result in improved management outcomes in terms of yields and incomes. Other than these two changes the farmers managed the plot in the same way as any other year and recorded any inputs and outputs from the system. Results from each of the experimental treatments are given below in Table 23, which shows that the best results were generated by the treatment where bhetki were not stocked and a pelleted feed applied.

Table 23 Results from the active experiment in the brackish systems in terms of wild species (fish and shrimp) yields, yields of stocked species and total income. Figures given for each treatment are the mean value together with the minimum and maximum (in brackets).

Treatment	Yield of wild species ($kgha^{-1}$)	Yield of stocked species ($kgha^{-1}$)	Total income ($INRha^{-1}$)
No bhetki, traditional feed formulation	156.1 (75.4, 223.1)	293.8 (142.7, 425.8)	34157 (19154, 46437)
No bhetki, pelleted feed	164.6 (90.4, 211.5)	297.3 (163.5, 346.2)	37204 (21442, 46665)
Bhetki stocked, traditional feed formulation	63.9 (19.2, 126.0)	177.8 (76.3, 279.8)	25818 (12570, 40577)
Bhetki stocked, pelleted feed	100.4 (53.8, 155.8)	242.2 (159.1, 330.8)	28836 (20841, 38538)

Analysis of the data collected at the site indicated that fish and shrimp production varied with the level of inputs of fish seed and was also affected by incidence of disease. In addition there were significant effects on yield from the stocking of bhetki, type of feed applied and the incidence of disease (Figure 32).

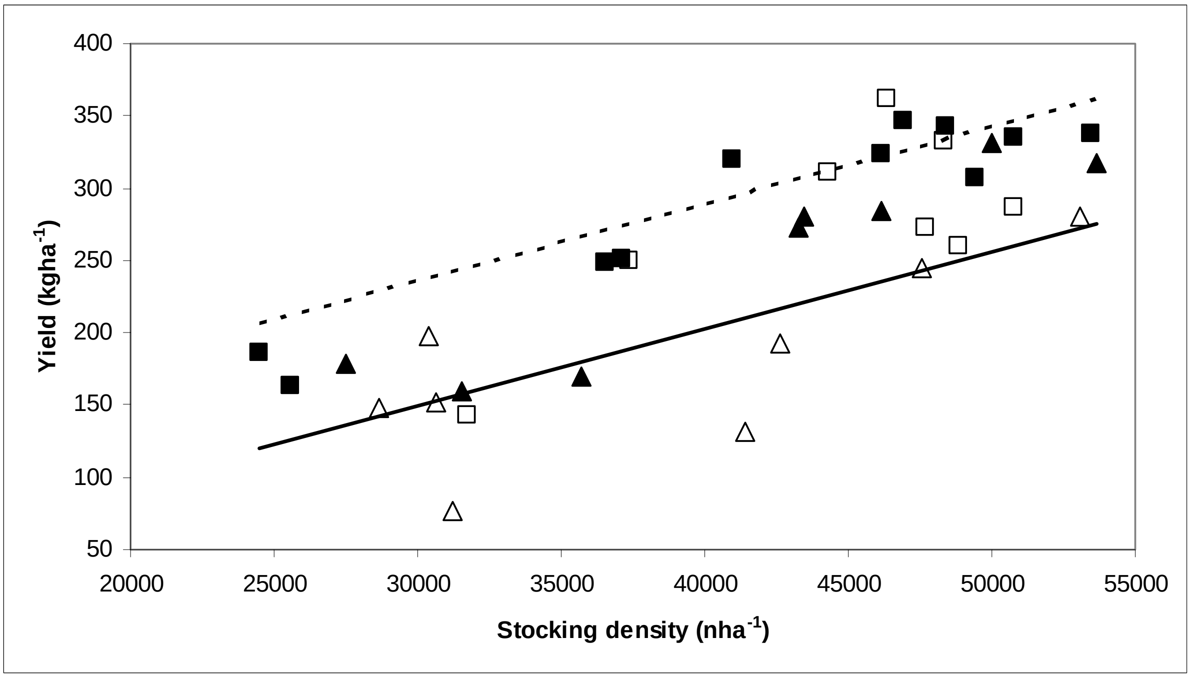


Figure 32 Relationship between yields and stocking density from the active experiment. Solid line indicates the effect of stocking bhetki (*Lates calcarifer*) and traditional feed formulation and dotted line indicates effect of not stocking bhetki and feeding pelleted feed on yields (bhetki stocking represented by triangles, pelleted feed by solid markers).

The relationship between yields and stocking density was best described by the equation:

$$Yield = 52.72 + .0053SD - 62.51Lates + 23.44Feed \qquad R^2=0.59$$

Where SD is the total stocking density, Lates is dummy variable representing the stocking (or not) of bhetki and Feed represents the provision (or not) of pelleted feed. Overall the results indicate that yields can be increased through altering management practices so that bhetki are not stocked, increasing yield by some 62.5 $kgha^{-1}$ ($P<0.05$), and so that feed is provided in pelleted form rather than the traditional moist form, potentially also increasing yields by an average of 23.4 $kgha^{-1}$ ($P=0.2$). The combined effect of the changes represents a potential increase in yields to farmers of around 15% over current yields.

Because the objective of the farmers is not only to provide fish for household consumption but also to generate income, it is important to also consider the effect of the experimental treatments on income (Table 23 and Figure 33).

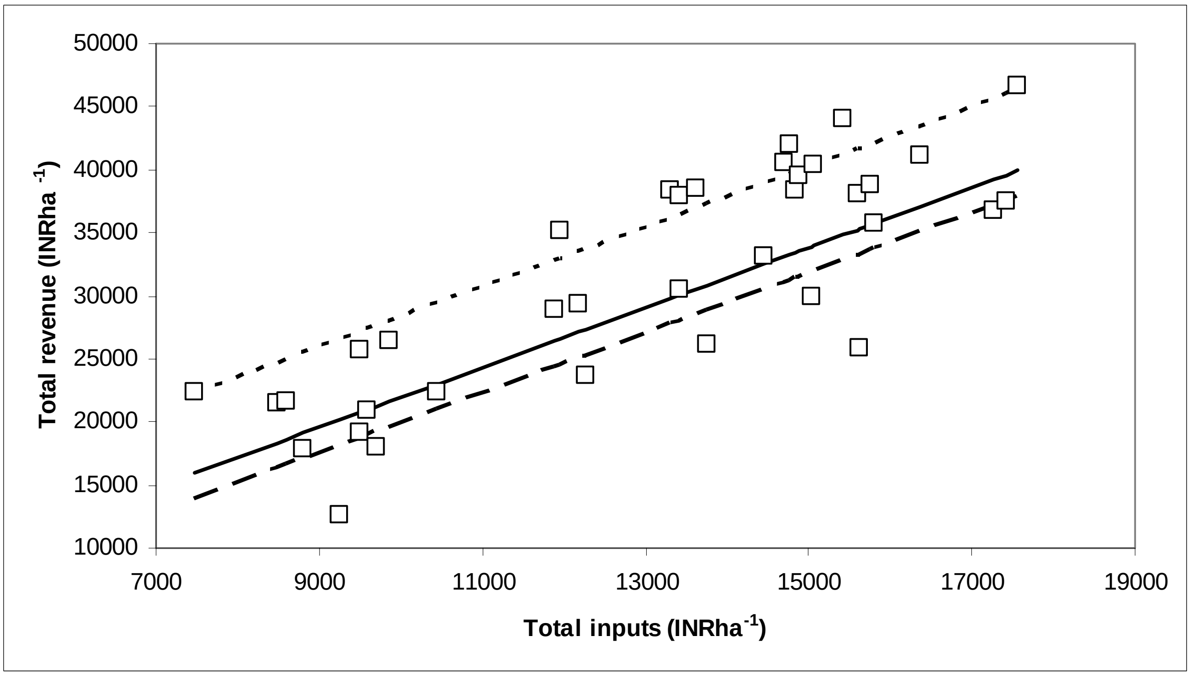


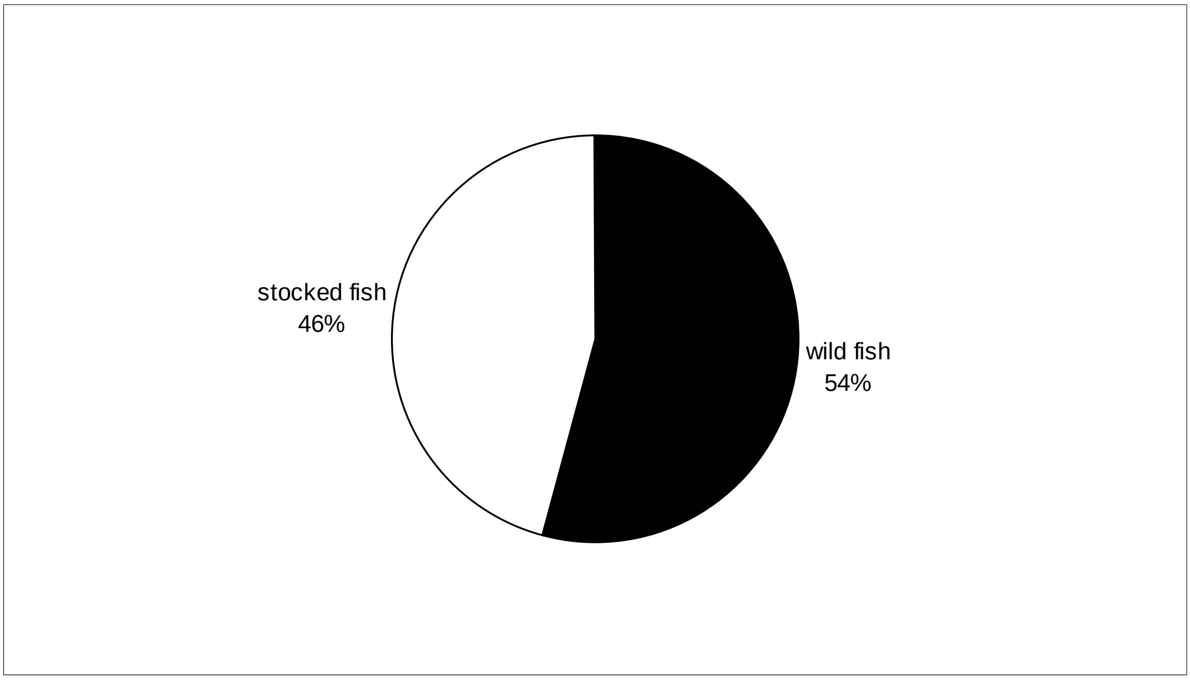
Figure 33 Relationship between income and inputs from the active experiment. Solid line indicates the effect of stocking bhetki (*Lates calcarifer*) and traditional feed formulation and dotted line indicates effect of not stocking bhetki and feeding pelleted feed on yields. The dashed line indicates the effect that disease had on the total income from the system.

The relationship was best described by the equation:

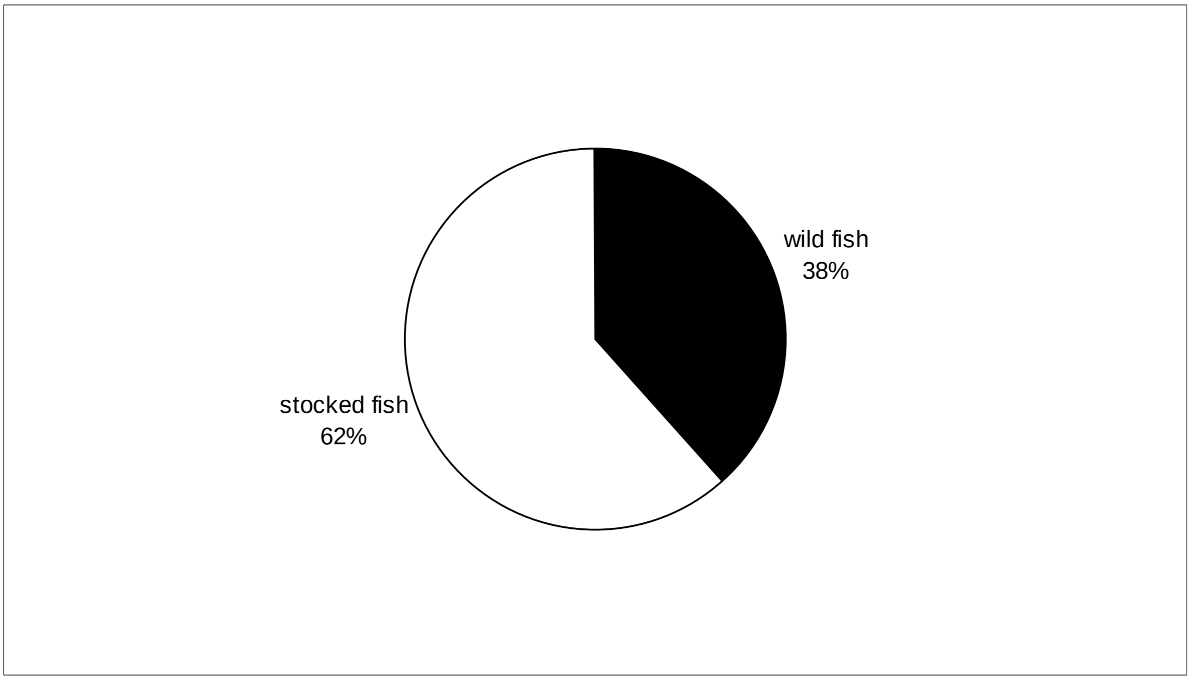
$$Income = 1167.21 + 2.38 Inputs - 3026.20 Lates + 3417.40 Feed - 4986.71 Disease \quad R2=0.84$$

Where Income is total income from the sale of wild and stocked species and Disease represents the incidence (or not) of disease. As can be seen, stocking bhetki again had a negative effect (P<0.05), reducing income on average by 3,026 INRha^{-1}and disease also reduced incomes (P<0.05) by some 4,987 INRha^{-1} on average. In addition to the negative effects, providing feed in pelleted form had a positive effect on income (P<0.05), increasing income by 3,417 INRha^{-1} on average. Again, the results suggest strongly that by discontinuing the stocking of bhetki and providing feed in pelleted form, farmer incomes could be increased by some 11%.

The negative effect that bhetki has on yields and incomes, despite it being a species that provides good returns (Figures 30 and 31), is due to the fact that it is a carnivorous species and that during the culture period it consumes smaller wild fish and also some of the stocked shrimp. While the effect of stocking bhetki on yields of *P. monodon* was found to be negative but not significant ($P>0.05$), the effect on wild fish yields was significant ($P<0.05$) with an effect of reducing yields of wild fish by about half on average. The effect on the species composition with and without bhetki in the stocked species mix can be seen in Figure 34.



a)



b)

Figure 34 Effect of stocking bhetki (*L. calcarifer*) on the catch composition a) without bhetki; b) with bhetki.

While it is possible that by reducing the population of wild fish and shrimp bhetki make more food and space available to the stocked component, thereby allowing more growth of the stocked species, the results were similar and no significant differences were found between the total yield per seed stocked with and without bhetki ($P>0.1$). The effect on yields and incomes therefore seems to be mainly due to the reduction in the wild fish contribution to total yield and income. In fact, the value of the wild portion of the catch in the waterbodies that were not stocked with bhetki was greater than the value of the bhetki catch plus the wild fish in those waterbodies that were stocked with bhetki (Figure 35).

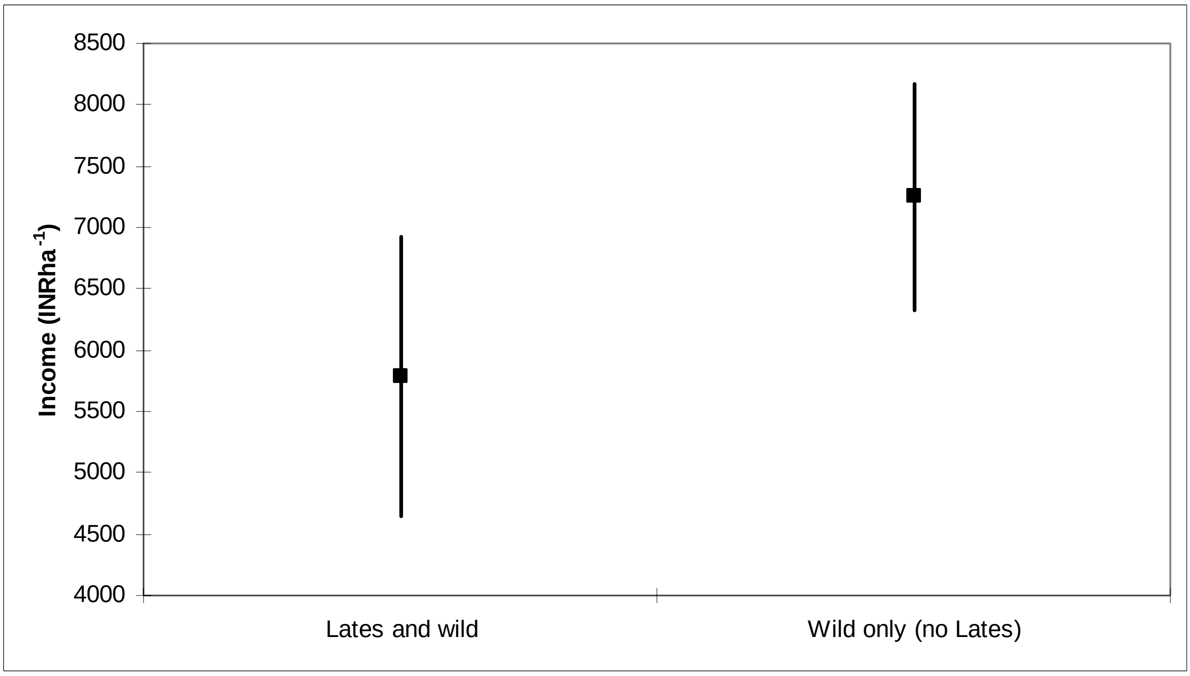


Figure 35 Income from bhetki (*L. calcarifer*) and wild fish components in the waterbodies stocked with bhetki and from wild fish only in those that were not stocked with bhetki. Bars represent the 95% confidence interval around the means.

The results have shown that there is potential to increase yields and incomes through changing feeding practice and not stocking bhetki. An additional wider benefit from these changes would be to make more wild fish and shrimp available to individual households and to the market. Given that these species have a low market price (Table 22) and are also preferred by a significant section of the rural population, there is the potential to increase the availability of a valuable protein source to the rural poor.

3.3.5.2 <u>Freshwater period</u>

During the freshwater culture period there were no active experiments conducted in the waterbodies. Farmers id however collect data on inputs and outputs from the waterbodies and this data indicated that the main factor influencing production was the stocking rate (Figure 36). The relationship was not particularly strong but did not appear to show any evidence of density dependence over the range of stocking densities observed.

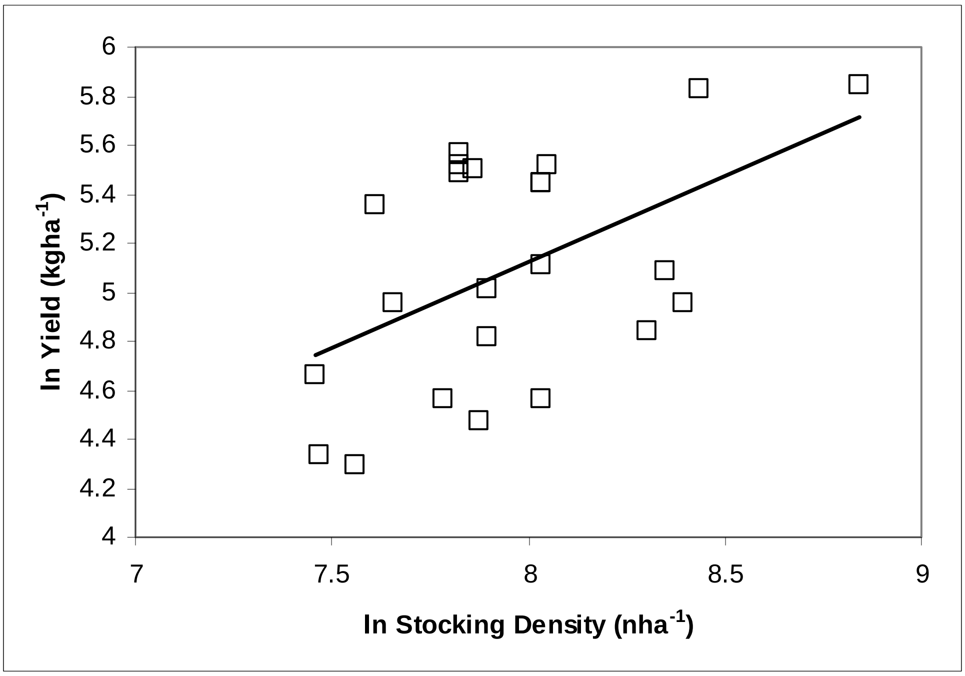


Figure 36 Relationship between stocking density and yield from the freshwater production cycle at Tangramari village.

3.3.5.3 Total production

The total production from the waterbodies at the brackishwater site was based on the data collected from 28 farmers. This indicated that over an entire year the mean total production of fish and shrimp was 1038 $kgha^{-1}$ (min: 375; max: 1610) and the mean income from this production was 92,282 $INRha^{-1}$ (min: 41,458; max: 161,613). This contrasts with the rice production from the same plots which was 823.5 $kgha^{-1}$ (min: 470; max 1180) with a value of 5,175.5 $INRha^{-1}$ (min: 2,980; max: 7,170).

Because of the harvesting system, marketing of fish is supply driven. Fish marketing arrangements are illustrated in Figure 37. As can be seen, the arrangements are simpler than for fish produced at the freshwater sites. This is due simply to the differences in the quantities of fish being sold, which make it uneconomic for the farmer to consider any other option than local marketing.

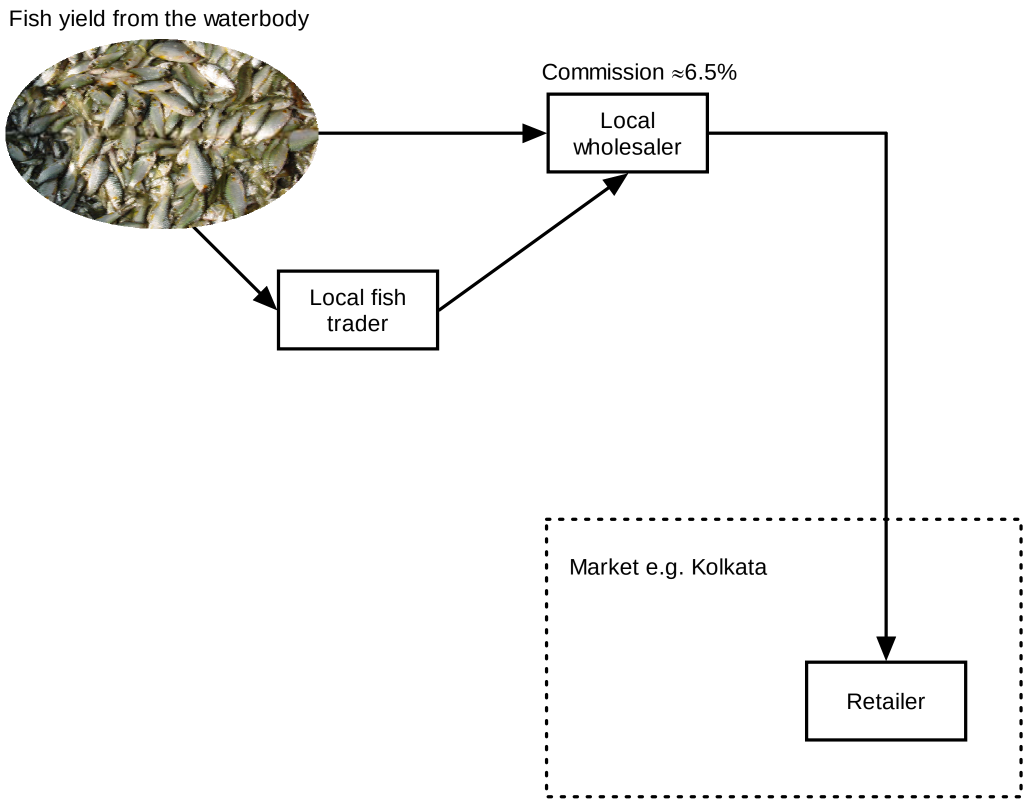


Figure 37 Marketing of fish from the brackish water sites.

Fish and shrimp are sold by the landowner at nearby Hasnabad where it is sold to wholesalers. If the catch is small (less than about 2 kg) then it is not worth traveling to the market and the fish is sold to a local fish trader in the village who will buy from a number of farmers in the village before taking the catch to sell in Hasnabad. Typical harvesting sizes and selling prices are given in Table 22. The market price depends on the size of the fish, with higher prices for larger fish.

All of the brackishwater impoundments at Tangramari village were managed in the same way, which was as a privately owned and managed system, each waterbody belonging to a single household. This meant that, while similar across all bheries, the distribution of benefits from the fisheries was quite different from the freshwater sites and included fewer beneficiaries. The distribution of benefits is shown in Figure 38.

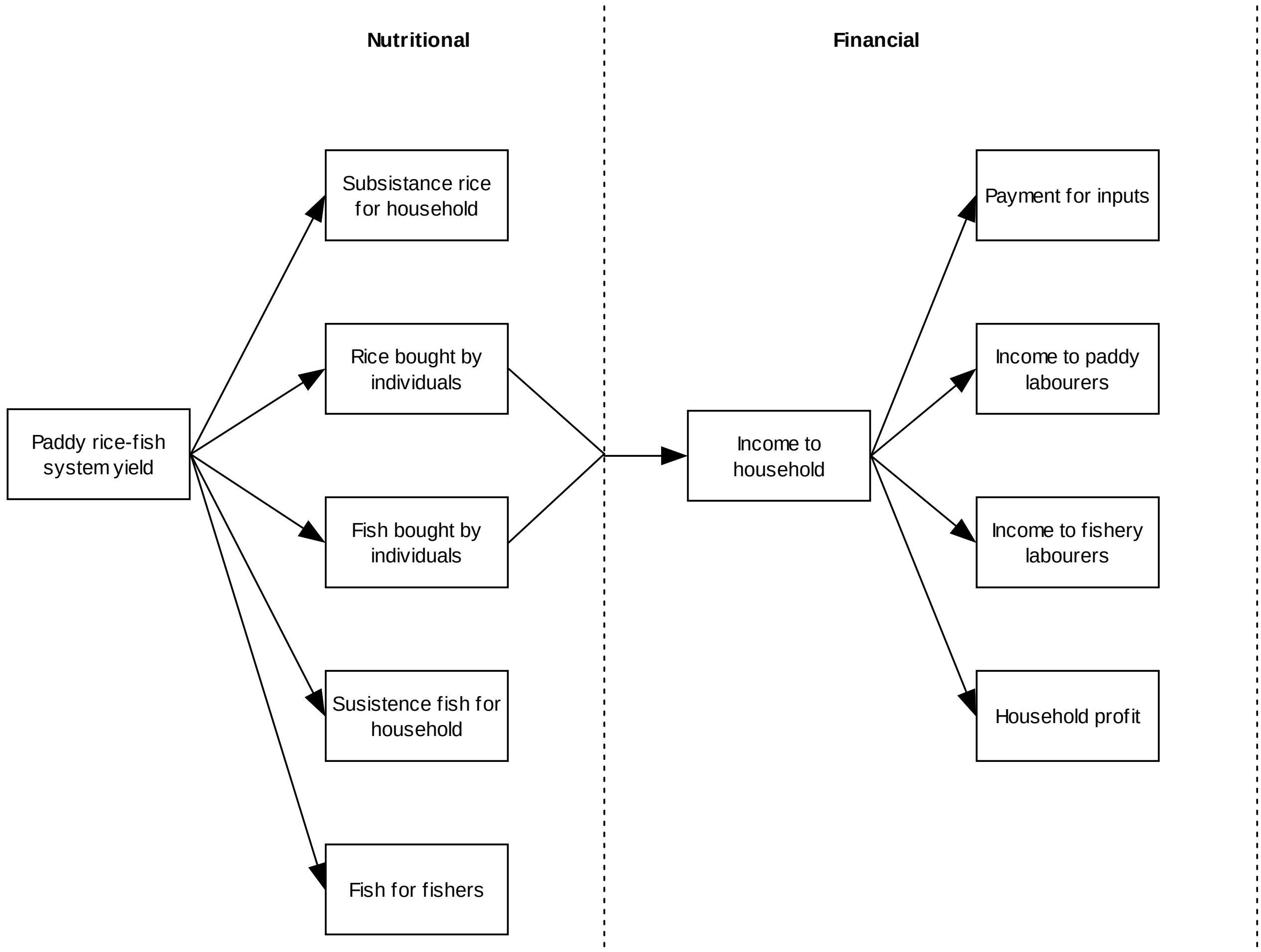


Figure 38 The distribution the different benefits from the household management of the waterbodies at the brackish water site.

Management constraints faced by the villagers were broadly similar to those at the freshwater sites with access to credit and technical information being amongst the main constraints. However respondents also stated that shrimp disease was a major constraint, and as this study has indicated, shrimp disease can have a significant negative effect on yields and incomes. The financial constraints faced by the farmers in Tangramari were similar to those in the freshwater sites in that, while the farmers could demonstrate ownership of the waterbody (unlike the renters at the freshwater sites), the land was in a marginal area and not recognized so credit was therefore not available.

4 Discussion

Overall the study has been successful in generating new knowledge about the resource systems and their dynamics that have contributed to reducing some of the key uncertainties that had been identified by farmers, district staff and researchers. The reduction of these uncertainties had the potential to lead to increases in both yields and incomes for those managing the waterbodies. Furthermore, the changes would lead both to increased supply of cheap fish, potentially benefiting the poor, and, in the case of the freshwater sites, increased income for village development. Following the sharing of the information generated from the study (detailed elsewhere), it was seen that lease prices increased by an average of 12%. This increased lease price meant that there was additional funds available to the village development committees. At the brackish water sites the results indicated that changes in management practices could increase yields by an average of 15% and incomes by some 11%. Not only are these fairly significant figures but it should also be borne in mind that these increases can be realized at little or no additional cost to the farmers, a crucial consideration in systems where the farmers rate access to finance and credit as the major constraint.

The rice trials were the less successful aspect of the experimentation. Unfamiliarity with the cultivation of the Jaya cross variety meant that the results with this variety were less than might have been expected. However, farmers did appreciate the potential benefits of due to the short growing duration (120 days) and the fact that the rice could be harvested leaving the stumps in the water. The decomposing stumps then provide nutrients, encouraging the growth of plankton. It was reported that there was better fish growth in those systems where Jaya cross was cultivated.

The results from the active experiments with fish in both freshwater and brackish systems indicated that there was potential for increasing production and yields. In both cases the experiments indicated that it was possible to increase incomes and the production of cheap fish that could benefit the rural poor at little or no additional cost. The experiments also showed the potential importance of wild fish in the catches from both fresh and brackish water systems and the impact that the stocking of *L. calcarifer* can have on the yields of these wild fish. The results suggest that the stocking of *L. calcarifer* can have a negative effect on yields and incomes as the value of the *L. calcarifer* and remaining wild fish yields is lower than the value of the wild fish yield where *L. calcarifer* is not stocked. In addition, it is these small wild fish that are the preferred food of poorer households at the study sites.

Passive experimentation during the study considered the costs and benefits of management systems. In no cases were there found to be examples of collective management of a shared resource. When considering community based management systems the rental systems, and the benefits from these systems, are often overlooked. It is hoped that this study has shown that there can be significant benefits to farmers and the wider community from rental arrangements and that in situations where conflict is likely, or where the opportunity cost of collective management may be high, then rental systems may represent a low cost option for management that avoids the enclosure of the resource and the resulting capture of the benefits by smaller groups. Where there are arrangements to equitably distribute the benefits from the resource systems and where collective management is either impossible or too costly, renting can represent a positive choice.

In both freshwater and brackish systems the constraints faced by farmers and fisheries managers highlighted the need for the provision of relevant technical information and solutions that could contribute towards meeting the objectives of the managers at little or no additional cost.

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6 Appendix A. Data collection form used to collect management information.

Management Monitoring Form

COMPLETE 1 FORM FOR EACH WATERBODY IN OUR STUDY EVERY 2 MONTHS

Section A - DETAILS OF INTERVIEW

Date		Respondent's name	
Monitoring period		Respondents's position	
Location			
Waterbody name			

Section B: RICE CULTURE

B1. What variety of rice are they cultivating ?		
B2. When was it established ?		
B3. Was it established as seed or transplanted ?		
B4. Have you used fertiliser ? (Y/N)		**check record book**
B5. Have you used pesticides ? (Y/N)		**check record book**
B6. How often is it applied ?		
B7. Have you employed anyone ? (Y/N)		**If "yes" if "no"**
B8. How much were they paid ? (INR/day)		**check record book**
B9. How many people did you employ		
B10. What did they do ?		
B11. Is it the same people each time ? (Y/N)		
B12. Are these people local ? (Y/N)		
B13. Are these people landless ? (Y/N)		

Section C - MAIN FISHERIES MANAGEMENT SYSTEM

PRIVATE MANAGEMENT (CO-OPERATIVE GROUP OR INDIVIDUAL)

C1. Do you plan to have (or have you already started) managing by yourself ? (Y/N)

If "yes"	Go to C2	If "no"	Go to C3

C2. Have you/they started fishing yet ? (Y/N)

If "yes"	Go to D1
If "no"	Go to E1

COLLECTIVE MANAGEMENT BY THE LANDOWNERS (NOT CO-OPERATIVE) Yes/No?

C3. Do you plan to have, (or have you already started) a collectively managed fishery ?

If "yes"	Go to C4	If "no"	Go to C7

C4. How many people are in the collective?

C5. What percentage of the landowners are in the collective?

C6. Have they started fishing yet ? (Y/N)

If "yes"	Go to D1
If "no"	Go to E1

RENTAL SYSTEM

THESE QUESTIONS TO THE LEASORS:

C7. Do you plan to (or have you already) rented the waterbody ? (Y/N)

If "yes"	Go to C8	If "no"	Go to C12

C8. What is/was rental price (INR)

C9. Have they rented yet ? (Y/N)

If "yes"	Go to C10
If "no"	Go to C12

THESE QUESTIONS TO THE LEASEES:

C10. How many people in the group renting ?

C11. Have they started fishing yet ? (Y/N)

If "yes"	Go to D1
If "no"	Go to E1

OTHER MANAGEMENT

C12. Do you plan to (or already have) another system of management ? (Y/N)

C13. What do you use the waterbody for ?

Section D: FISHING AND MARKETING

if they have said they are fishing check record book

Fishing

	Fishers	Sellers
D1. How many people are there each time ?		
D2. Is it the same people each time ? (Y/N)		
D3. Are these people local ?		
D4. Are these people landless ?		
D5. How much do they get paid (day/hour)? (include both cash and other - e.g. fish)		

Marketing

D6 Do they take the fish to the market to sell themselves (Y/N)		
D7 Do they wait for traders/buyers before they fish (Y/N)		trader/buyer
D8 Do they catch fish first & then wait for traders/buyers (Y/N)		trader/buyer
D9 If selling to traders, where do the traders sell the fish ?		

Section E: MONITORING AND ENFORCEMENT

Monitoring

E1. Who monitors the waterbody ?

E2. How do they monitor ?

E3. Do they get paid ? (Y/N) how much?

(include both cash and other - e.g. fish)

Penalties

E4. What are the penalties for illegal fishing?

Since the last interview

E5. Has illegal fishing occurred ? if yes, specify number of times

E6. Was anybody caught ? (no of people)

E7. What penalty was given ?

Section F: MANAGEMENT COSTS AND BENEFITS

Costs of management since last interview

F1. Have you used fish feed ? (Y/N) **If "yes", F2 If "no", F5**

F2. How much feed (kg) ? Cost (INR)

F3. What type of feed (bran/cake/pellet) ?

F4. Local feed or manufactured ?

F5. Have you used pond fertiliser ? (Y/N) **If "yes", F6 If "no", F9**

F6. How much fertiliser (kg) ? Cost (INR)

F7. What type of fertiliser (manure/P/N) ?

F8. Local source or manufactured ?

F9. Have you used pumps? (Y/N) **If "yes", F10 If "no", F13**

F10. How many pumps? Cost (INR)

F11. How many days

F12. How much gasoline Cost (INR)

General management

Time costs

F13. How often do the management group meet every month ?	
F14. How much time is spent discussing and making decisions each month ?	

F15. Any other costs for management ?(Y/N)

What for ?

Cost (INR)

Benefits

F16. What is the total income from the fishery this year ? INR

F17. How is this shared between the group ?

(by land area/ by investment/other)

Section G: PROBLEMS & SATISFACTION

Have villagers had problems with any of the following?	**Write down what the problem is**
Problems since last interview:	
G1. Monitoring the waterbody ?	
G2. Finding time to manage waterbody?	
G3. Group conflict or disagreement ?	
G4. Renting the waterbody ?	
G5. Finding people to employ ?	
G6. Flooding ? (affecting rice or fish?)	
G7. Waterbody drying up ?	
G8. Fish/shrimp disease ?	
G9. Catching fish ?	
G10. Selling the fish ?	
G11. Fish damaging rice ? (species)	
G12. Rice disease ?	
G13. Rice pest ?	
G14. Other ? (specify)	

Evaluation of rice cultivation

G15. What rice varieties are they growing ?		
G16. Are they satisfied with rice variety ? (Y/N)		specify
G17. Are they satisfied with rice yield ? (Y/N)		specify
G18. Are they satisfied with income (Y/N)		specify

Evaluation of fish culture

G19. Are they satisfied with fish catch ? (Y/N)	
G20. Are they satisfied with income (Y/N)	
G21. Are they satisfied with management system?(Y/N)	

For G16 - G21 Why / Why not ?

SECTION H - SITE RECORD BOOK

Ask to see the village records & check the village records

	Yes/no	Remark
H1. Did you see the records ? (Y/N)		
H2. Are the records being kept well ? (Y/N)		

If the answer is "no" to either question H1 or H2 please explain to the record keeper how to do and ask them to do in this way in the future

After looking at the records ask:

H3. Has any fish (stocked or wild) come out of the waterbody that is NOT written in these records

If yes, what

SECTION I - INTERVIEVER EVALUATION

I1.Do **YOU** think the waterbody is well managed (why/why not?)

I2. Are they keeping records well?

I3. Is there any other information from this interview that you think is interesting for our study?

Enumerator signature	
CIFRI staff signature	

Appendix B: Example of a village record book.