# Results of the rapid appraisal to investigate the status of rice-fish culture in brackish and fresh water in West Bengal, India

MRAG Ltd
2004

## Acknowledgements

It is important to thank the following people for their involvement and contributions to the appraisal. From CIFRI in Barrackpore Dr U. Bhaumik and Dr T. Paria made important contributions to the data collection including participation in fieldwork, contributions to the methodologies and in providing additional data and information. Dr N.K. Saha and Dr S.K Bardan Roy of the Department of Agriculture in West Bengal are also to be thanked for their contributions to the methodology and for supplying additional data and information about rice-fish systems in West Bengal. Also from the Department of Agriculture, Dr P. Roy Chowdhury also contributed to the data collection process. In addition, the appraisal could not have been conducted without the involvement of Dr D. Nath, the Director of CIFRI and the active participation of Block and District staff from both the Department of Agriculture and the Department of Fisheries in West Bengal, and of course, the fishers, and representatives of fisher cooperatives at each of the sites visited who were prepared to give up their time and who participated so enthusiastically.

This document is an output of the FMSP project R8292 – Uptake of Adaptive Learning funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

# Table of contents



Cover photo: Creating a seasonal calendar to investigate land use and rice-fish cultivation at Kamardanga village.

## List of Tables

## List of Figures

# List of Plates

# 1 Introduction

The importance of rice and fish to the livelihoods of the rural poor in Asia is immense. Rice and aquatic organisms, primarily fish, are considered to be the two main sources of food in this region. Indeed, rice is believed by Hassan (2001) to constitute as much as 60% of the daily food intake of the majority of Asians while fish is widely considered to be the major source of animal protein for the majority of people in Asia, including West Bengal, and a major source of vital micro-nutrients (Demaine and Halwart 2001, Hassan 2001). Freshwater fish in particular, because of its relatively low price, is believed to be a vital source of animal protein for lower income groups (FAO 2001). Over ten million hectares, representing approximately 15% of the total land in Asia available for rice culture, is subject to flooding. Of this, over half these lands are located in the Indian subcontinent, mainly Eastern India and Bangladesh (WorldFish 2002). The floodplain areas provide a predominantly freshwater environment for the culture of rice and freshwater fish and shrimp[1]. In addition, 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.

The development of irrigation and water control systems has enabled farmers in the region to grow higher yielding rice varieties (*Boro* rice) in the dry season as well as, or instead of, the more traditional rainy (post-monsoon) season deepwater varieties (*Kharif* rice). In freshwater areas where water control is not possible and irrigation unavailable the practice is to have a single crop of *Kharif* during the rainy season while in deep flooded areas it is to have a single crop of *Boro* rice (WorldFish 2002). In brackishwater areas, water salinity means that land use has traditionally been restricted to a single crop of *Kharif* rice following the monsoon rains (Bardan Roy *et al*. 2001). The rice cultivation practices, the availability of water for at least four months and demand for fish provide opportunities to increase the productivity of the system and meet this demand by including a crop of fish and/or shrimp to create a rice-fish system. The fish/shrimp crop may be grown either following the rice crop or at the same time depending upon the nature of the system.

Enhancement of rice-fish systems, through stocking, is an idea that is gaining in popularity with governments, NGOs and local communities throughout South and Southeast Asia and is seen as one of the principle means of addressing their wider objectives and improving the livelihoods of the rural poor as well as meeting the increasing demand for fish. It is worth noting in this respect that in West Bengal, it is estimated some 94% of farmers may be classed as poor (Economist, 2004). It has been found that enhancement initiatives can increase overall yields and substantially increase income from the system and, where fish is cultured alongside rice, the rice yields can be improved (e.g. WorldFish 2002, IIRR 2000, Sinhababu *et al*. 1984, Bardan

[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.

Roy *et al*. 2001). 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,). In terms of the fish component, which this report will concentrate upon, experience with enhancement initiatives in rice-fish systems and other small waterbodies have 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). Often it is said that the results from field trials are less than those of experimental trials. 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 potential to improve the management of culture-based fisheries in rice-fish systems. 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, could potentially yield even greater benefits (Garaway *et al*. 2002 and Peterman and McAllister 1993).

One of the first steps in the adaptive learning approach is to create a common understanding the resource systems amongst stakeholders, including the users and managers, extension workers, researchers and others – groups that often have different perspectives and knowledge relating to the resource system (see pages 18 and 19 of Garaway and Arthur 2002). In order to take an adaptive learning approach with the management of community fisheries in West Bengal, it was therefore necessary to identify sites where rice-fish culture was already being conducted. These sites could then form the basis for understanding the systems, identifying uncertainties associated with the systems and identifying sites that could potentially be involved in an adaptive learning experiment, either passive and/or active. This report therefore outlines the initial steps including the collection and subsequent analysis of secondary and limited primary data relating to the fishery component of rice fish culture systems in West Bengal, India.

## 1.1 Specific objectives

The objectives of the appraisal were:

- To characterise the management systems, including the objectives and constraints, currently operating within West Bengal;
- To collate information about the bio-physical nature of these systems within the study area;
- To conduct an initial assessment of the outcomes of management of these systems in order to identify any uncertainties that could potentially be reduced through an adaptive learning strategy.

# 2 Methods

The study was conducted within the districts of Hooghly, North 24 Parganas, South 24 Parganas, Hashnabad, East Midnapore and Durgapur in the state of West Bengal in eastern India over a four week period in January and February 2004. Sites to visit were selected based on information provided by CIFRI, West Bengal Department of Agriculture and district level government staff about the abundance of rice-fish culture sites within the state.

## 2.1 Framing the enquiry

It was important that the baseline study included an assessment not only the biophysical aspects of the resource systems but also the institutional arrangements and socio-economic aspects. This is because it has been recognised, for example by Grover (2001), and Lorenzen and Garaway (1998), that even technical management actions can have non-technical outcomes. Because of this, it is suggested that there is a need to gain an understanding of the wider social, economic and institutional environment in which management operates (Grover 2001, Scoones 1999, Lorenzen and Garaway 1998, Dovers and Mobbs 1997, Bosch *et al.* 1996).

Research on common-property resources has led to the development of a framework that enables analysis of how the outcomes of management are determined by interactions between the bio-physical characteristics of the resources and the institutional, social and economic setting in which they are utilised (Oakerson 1992). This framework, shown in Figure 1, is increasingly being used in fisheries research, including fisheries enhancements (Garaway *et al*. 2002, Lorenzen and Garaway 1998, Cowan *et al*. 1997, Hartmann 1995).

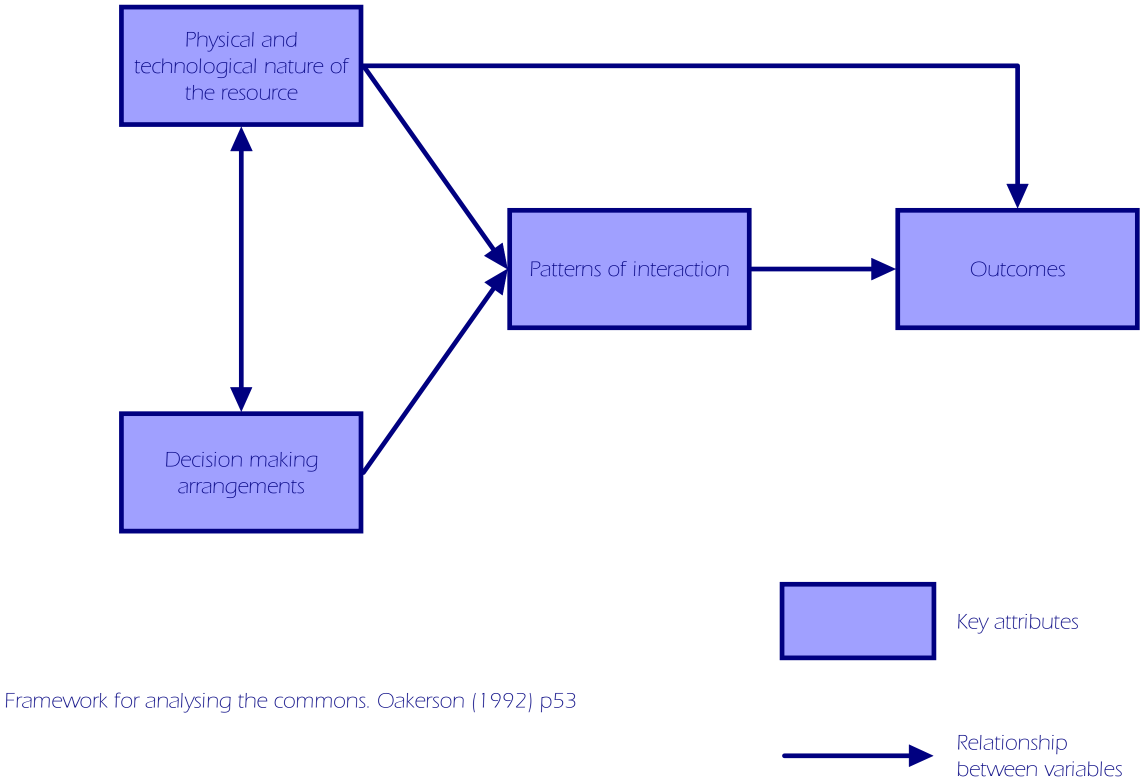



**Figure 1 The Institutional Analysis and Design framework used to frame the enquiry.**

The framework describes the resource system in terms of four main attributes (the boxes in Figure 1) – biophysical and technical attributes of the resource, decision-making arrangements, patterns of interaction and outcomes. Decision making arrangements consist of the operational rules, i.e. rules that determine where, when, how and by whom resources may be used, conditions of collective choice, i.e. the set of rules determining how the operational rules are created and the external arrangements that constrain the rules and conditions of collective choice. The patterns of interaction are the sum of all individual actions made by resource users and the outcomes are the patterns of production and consumption from the resource system, to each of which will be attached stakeholder values.

Relationships between variables are shown as arrows in Figure 1. Some attributes of the resource, such as natural productivity, will affect the outcomes of resource use independent of the actions of resource users (top arrow). Such a relationship will constrain the achievable outcomes. Other attributes will affect outcomes by influencing the actions of resource users, for example the location of the resource may make poaching an option. The attributes of the resource, along with the rules in place for its use (arising from the decision making arrangements) provide the setting in which individual users can make decisions regarding the resource. Their resulting actions, the patterns of interaction, will then directly affect the outcomes.

The framework was used as a tool to frame enquiry into enhancement fisheries and to ensure that relevant information that would provide a full picture of all attributes of the resource system was collected.

## 2.2 Appraisal team

The study was conducted in association with government staff from both CIFRI and the Department of Agriculture of West Bengal. In addition, district and block officers of both the state Department of Agriculture and Department of Fisheries were involved in the appraisal. District and block officers were familiar to the resource users and managers at the sites visited, making the appraisal team more acceptable and aiding communication with them (see MRAG *et al*. 2004 for further details of the stakeholder groups to be involved in the learning process). Because of constraints on availability of key personnel, the make-up of the appraisal team varied over the study period but was generally comprised of a fisheries biologist, an extension specialist or other[2] familiar with the site who assisted in the appraisal as facilitators and translators and up to three district and block level staff who each had in-depth knowledge of the local area and would also accompany the group and assist in showing the site and providing background information.

## 2.3 Initial site identification and selection

The districts in which the appraisal was to be undertaken and the adaptive learning approach implemented were selected after discussion with CIFRI and Department of Agriculture staff. The initial selection of districts was based on the fact that there were many sites in these districts where rice-fish culture is practiced (freshwater and/or brackishwater). Thus there exists the potential to select sites for inclusion in the adaptive experimentation and also to extend any results from the study to other nearby sites through the extension staff thereby increasing the impact of the project.

Once the districts had been identified, basic information on sites within each, seasonal variation and management characteristics, was collected from each participating district. This information included details about waterbody size, annual variation, seasonal land use and whether or not the waterbody had been stocked and the system of fishery management (private ownership, community management or leasing) employed for the waterbody. The information, collated on a simple form designed in collaboration with CIFRI and DoA staff (see Appendix 1), was based on district records and the knowledge of district and block staff.

The number of potential study sites in each district varied and the extent to which the form was completed also varied with no forms completed for Durgupur or South 24 Parganas and only a single form completed in North 24 Parganas. On the basis of the information available, sites were selected as potentials for inclusion if they satisfied the following criteria:

[2] The fisheries biologist was supplied by MRAG Ltd while the extension specialist or other person or persons were staff from CIFRI and/or the Department of Agriculture, West Bengal.

- Sites has some form of rice-fish culture ongoing;
- The fishery was culture-based, including the harvesting of both wild and stocked fish rather than exclusively based on cultured fish (aquaculture);
- The fishery was primarily benefiting the poor.

The number of potential sites was far greater than the time available to survey them all and therefore a further selection was made on the basis of CIFRI and Department of Agriculture expertise to ensure a wide coverage of sites across all participating districts, freshwater and brackishwater sites and a variety of management systems and stocking activities. A total of 30 waterbodies at seven sites were selected for the appraisal.

## 2.4 Information requirements for the appraisal

The appraisal that was conducted was centred on informal interviews with key informants at each of the sites selected. These were aimed at providing information about both the biophysical nature of the resource system, the management of the rice-fish systems and the outcomes of this management. More in-depth biophysical sampling had originally been planned as part of the appraisal but due to logistical and organisational constraints the appraisal was conducted in January/February, a time when water levels are low, rather than the planned October/November. This meant that sampling was not possible and greater reliance has had to be placed on secondary data and the responses of the key informants. Secondary data sources for the appraisal included published articles, project documents, government statistics and maps of the local area.

The information to be collected using semi-structured interview techniques at each site was based on the IAD framework. The types of information to be collected was discussed with researchers from WorldFish Center, CIFRI and DoA to ensure that all the questions were relevant and that all the important aspects of the system were adequately covered. Following discussions, a list of subjects that were considered by all to be worth exploring was drawn up and agreed upon (Table 1).

**Table 1 Information collected in the rapid appraisal.**

| Subject area | Data to be collected |
|---|---|
| Background village information | Location of nearest markets<br>Location of nearest seed supplies<br>Organisational structure of the village<br>Relative importance of fish in household nutrition<br>Sources of fish for household consumption |
| Management of the waterbody | Use of the waterbody over the year<br>Rice varieties grown<br>Objectives of fishery management<br>Management regulations in place<br>Monitoring of the waterbody<br>Enforcement of regulations<br>Income estimate<br>Relative importance of income from fishery<br>Stocking practices<br>Maintenance and enhancement activities<br>Problems and constraints associated with management<br>Future management plans |
| Fishing practices | Gears used<br>Effort estimate<br>Yield estimate |
| Biophysical characteristics of the waterbody | Waterbody area<br>Depth<br>Water control methods<br>Salinity<br>Productivity<br>Annual variation associated with the waterbody |

### *2.4.1 Semi-structured interviews*

Semi-structured interviews were used to collect information about many aspects rice-fish systems and their management. This included the decision-making arrangements, patterns of interaction and outcomes of management. These interviews were accompanied by a review of relevant secondary data for background information. Instead of formulating detailed questions ahead of time or creating a formal questionnaire, as in a fully structured survey method, the semi-structured interview technique relied on a checklist that identified a particular set of subtopics relevant to the wider issues being investigated. Interviewing was then conducted using this checklist to guide the specific questions that were themselves improvised during the interview. This had the added benefit of allowing a more relaxed and conversational feel to the data collection. The interviews were held with individual landowners, members of fisheries cooperatives and/or representatives of the group that were renting the waterbody and managing the fishery.

The use of a checklist ensures that all the points are covered while at the same time allowing flexibility to probe for detail and thereby gain a better understanding of local variation. Respondents were provided with scope to express opinions and to describe in more detail their particular situations. Questions that enabled them to do this were vital in providing an understanding of why certain actions had or had not been taken in relation to the resource systems.

In addition to, and as a part of the interviews, the informants were asked on occasion to create maps using a large sheet of paper and coloured marker pens that detailed the position of local water resources and nearby villages and indicated the nature of local land use. In addition, seasonal calendars and matrices were used to explore aspects of the management at each site and questions would then be asked based on these visualisations to elicit more information and provide more detail on the management at each of the sites (for example see Plate 1). In addition, an effort was made to use local weights and measures where possible to make it easier for the respondent. This required some care as some units such as the bigar (measure of area) vary by location so it was also important to check the relative value of such units.

**Plate 1 Creating a seasonal calendar to explore aspects of resource system management at Tangramary village (Source: R. Arthur).**

Rules and techniques that improve the quality and efficiency of semi-structured interviewing were considered and followed during the research, particularly those set out by (Grandstaff and Grandstaff 1985). These involve issues such as: procedures for setting up interviews (who to interview and where); controlling the interview; judging the responses of informants; probing; avoiding certain question types (e.g. leading questions); and, non verbal factors (awareness of body language, dress, local protocol).

### *2.4.2 Limitations and problems encountered*

There were a number of limitations to the information collection. The first, and major constraint, as already mentioned, was that the appraisal was collected at a time of low water that meant that opportunities for biophysical sampling had been missed. The organisational difficulties also imposed further limitations on time and resources. Key personnel were not always available so that the composition of the appraisal team varied over the study period, adversely affecting both continuity and consistency in the interviewing. Time was always a major constraint, and the study period was a very short time in which to collect data on such a wide range of attributes and outcomes in resource systems that varied in nature quite considerably in both biophysical and institutional aspects. The time that it takes to perform and interview together with the distances between sites severely limited the number of sites that could be included in the appraisal. All of this has meant that there is a much heavier reliance on secondary data than would be desirable.

# 3 Results

The results of the appraisal will be presented in terms of the IAD framework. The seven sites that were visited varied quite considerably in nature and there was a great deal of variation also in the number of people benefiting from each system and in the livelihood strategies employed by those managing and/or reliant upon the resource systems.

## 3.1 Biophysical and technical attributes of the resources

The sites visited varied considerably in the biophysical and technical nature of the resource system. Farming practices in floodplain locations such as the study sites are influenced to a high degree by physical factors including location, flooding (onset, depth, recession and variability/controllability) and water management, topography, rainfall, soil texture and chemistry and water chemistry (WorldFish 2002, Chakraborti and Bhowmik 1985, Bardan Roy *et al.* 2001). In the first place, sites could be categorised as either brackishwater or freshwater systems. The salinity of the water being an attribute that placed certain constraints on the management actions, both for rice cultivation and fish culture that could be considered.

With regard to salinity, many of the brackishwater sites visited were situated on the Hooghly-Matlah estuarine system, part of the Ganga river system, one of the major Indian river systems. Following the construction of the Farakka Barrage on the River Ganga in 1975, changes in water chemistry in the estuarine system have been noted, resulting from the additional discharges of freshwater into the system. Lal (1990) and De and Sinha (1997) both describe how the barrage has resulted in lower salinity levels in the middle and upper parts of the system. In certain places the salinity is reported to have reduced from around 15 ppt to nearer 8 ppt. The reduction in salinity has also been accompanied by lower levels of turbidity (De and Sinha 1997) and reduced nutrient (phosphate and nitrate) levels (Lal 1990).

### 3.1.1 *Waterbody biophysical characteristics*

Location of the waterbodies can act to provide constraints and opportunities to management. For example, if the site is located far from a market or seed supplier the management options may be fewer or different from sites where these are more accessible. Table 2 shows the location of sites surveyed in the appraisal relative to these.

**Table 2 Location of sites surveyed relative to markets and sources of fish seed.**

| Site | Market | Market distance | Seed source | Seed source distance (km) |
|---|---|---|---|---|
| **Freshwater sites** | | | | |
| Pearypur | Seorafuli | 15 mins | Bankura and Adisaptogram | 130<br>14 |
| Mohantiki | Muthiparah | 20 mins | Ramsagar | 47 |
| Kamardanga | Guptiparah and Sombrah | 25 mins<br>25 mins | Local hatchery | 10 |
| Janakichak | Annapurna | 10 mins | Within district | Up to 30 |
| **Brackishwater sites** | | | | |
| Jorria | Harawa and Barashat | 15 mins<br>45 mins | Fish within village, shrimp from Namtaka and Hashnabad | 0 |
| Tangramary | Hashnabad | 15 mins | Fish from Bakura, shrimp from river | 0 |
| Bedemary | Hashnabad | 45 mins | Seed trader | 0 |

While the sites visited in the appraisal all represented flooded areas, the sites quite varied in a number of key factors, as is shown in Table 3.

**Table 3 Some key biophysical characteristics of the waterbodies included in the appraisal.**

| Site | Waterbody | Maximum waterbody area (ha) | Fish culture period | Salinity | Empoundment | Water control | Maximum depth (m) |
|---|---|---|---|---|---|---|---|
| **Freshwater sites** | | | | | | | |
| Pearypur | 1,2,3,4,5 | 3, 1.5, 1, 2, 1.5 | June - Dec | No | High | Canals and pump | 1.5 |
| Mohantiki | Mohantiki | 8 | May - Jan | No | Low, single dyke | None | 2.5 |
| Kamardanga | Dhama | 100 | June - Dec | No | Low, single dyke | None | 4 |
| | Camner | 30 | June – Dec | No | Low, single dyke | None | 2 |
| Janakichak | 6 waterbodies | 8-67 | June - Dec | No | Low | Canals and weirs | 1.2 |
| **Brackishwater sites** | | | | | | | |
| Jorria | 1,2,3,4,5 | 29, 5, 2, 16, 21 | Feb - July | Low to Med | Low | Canals and weirs | 1 |
| Tangramary | 10 waterbodies | 0.3-0.5 | June – Dec* | Low to Med | Low | Weirs from main river channel | 0.5 - 1 |
| Bedemary | 1 | 0.3 | June - Dec | Low to Med | Low | None | 0.5 |

* Also culture shrimp Jan - May

The area available for cultivation and access to water are considered to be the most critical resource for the farmers. In the case of the fish component of the system the inundated area is of importance. Where this area is large, the cost of stocking at densities often recommended (often 2000-4000 fingerlings (5-10cm) per hectare) can be prohibitive. A large inundated area may also mean that there are large numbers of stakeholders with implications for management arrangements. In such cases, a reduction of the culture area, for example through pens, may be considered. In smaller systems, such as the individually owned and managed systems the area available for fish culture may limit yields. Where the system is based on impoundment and control of water (e.g. site 1), the costs of impoundment may limit the area available for cultivation.

Aside from the area available, the availability and controllability of water and the depth of water in the system will affect the decisions regarding fish culture and the potential yields. Water depth can be increased through empounding an area by building bunds, a feature at all of the sites and controlling water through pumping or canals and sluice gate systems (see Plates 2 and 3). In addition, trenches may be dug in parts of the waterbody to create areas that are much deeper and that act as a refuge for the fish. These are common modifications to paddy fields and small waterbodies to enable improved fish culture (e.g. Garaway *et al*. 2002, Demaine and Halwart 2001 and Kangmin 2001).

**Plate 2 Control of water achieved through high bunds and pumping water from nearby irrigation canal at Pearypur. Note rice paddies in the background remain fallow (Source: R. Arthur).**

**Plate 3 Control of water through bunds, sluices and canals at Jorria. Seen here is a sluice gate supplying water to the waterbody from the main water channel (Source: R. Arthur).**

The degree of water control has implications for the yields of fish from the system. If no water is available for part of the year then the options for fish culture are reduced. The type of water control is also an important factor in that pumping water does not allow wild fish to enter the system while, at the other end of the extreme, flooding, particularly where it results in unrestricted connections between waterbodies enables wild fish to freely move into the system. For example, Reshad Alam *et al*. (2001) have found that the yield of wild fish from such systems is positively correlated to the period of inundation as wild fish have longer to move between systems.

Soil and water chemistry can be an important factor that affects management in both freshwater and brackishwater systems as these have a direct effect on the productivity of the system in terms of both the rice and the fish (WorldFish 2002, Kumar 2002, Sinhababu *et al*. 1984). For fish, the productivity of the waterbody is an important aspect to examine in these small waterbodies because, as Lorenzen *et al*. (1998a), Quiros and Mari (1999) and Milstein (1992) amongst others suggest, in extensively managed systems such as these the yields are likely to be influenced by the trophic level of the waterbody and the stocking density.

Water chemistry can affect the species of fish that can be stocked with more saline waters suitable for the high value penaeid shrimp (e.g. *Peneaus monodon* and *P. indicus*) and euryhaline tilapia (*Oreochromis niloticus* and *O. mossabicus*) beckti (*Lates calcarifer*) and mullets (*Liza* sp.) while less saline waters are more suitable for freshwater species such as the Indian major carps (*Catla catla*, *Cirrhinus mrigala* and *Labeo rohita*), Common carp

(*Cyprinus carpio*), Chinese carp (e.g. *Aristicthys nobilis, Ctenopharyngodon idella* and *Hypopthalmicthys molitrix*) and tilapia. In addition, some species, in particular tilapia, are more suited to more productive waterbodies and may not do well in waterbodies of low trophic status (e.g. Arthur 2004, Garaway *et al*. 2002). It was found during the appraisal that the soil and water chemistry, in particular the nutrient content could greatly affect the price that could be obtained for leasing and this would also influence decisions about stocking and about rice cultivation (see section 3.4.1).

Where the salinity of the water available in the dry season was fairly high, attempts were made to culture Penaeid shrimps, often together with saline-tolerant species of fish during the traditional fallow period. Saline water was taken from nearby rivers during this time to allow a crop of shrimp and fish to be harvested before the monsoon. During the monsoon, and as long as the water salinity has not been too high, the high rainfall very effectively desalinises the soil and enables *Kharif* rice culture to be carried out (Natarajan and Ghosh 1982). This form of management has been recommended only for those areas in the middle to upper reaches of the estuary as even after the rains, the soil salinity is increased compared to paddy only systems and generally requires the cultivation of saline tolerant species of rice (Chattopadhyay *et al*. 1983, Chattopadhyay *et al*. 1982).

In a number of areas, the profitability of the shrimp culture is such that the rice crop has been abandoned in favour of a second crop of shrimp and fish. While more profitable than rice, in the more saline areas this effectively means that the system cannot be reverted to rice-fish as the soil salinity over time becomes too high. Such systems were most common in the more productive waters, e.g. in South 24 Parganas. These systems were stocked with *P. monodon*, fertilised and provided with additional feed as necessary to maximise the production from the systems. This is a similar system to that described by Kumaran *et al.* (2003) for farms in Andhra Pradesh.

### *3.1.2 Stocking*

All of the waterbodies at the sites visited had been stocked at some point and all were currently stocked annually. The timing of the stocking events differed depending upon the nature of the resource but the majority were stocked in May to July (see Table 3). This was at the time when the flooding had occurred and the waterbodies were at their deepest, and provided the maximum culturing period and lowest risk of further flooding. The exception to this was Jorria and in this case the water supply to the waterbodies was controllable allowing the farmers some freedom to decide when to culture fish.

Fish fingerlings were obtained from variety of sources including markets, village sources, travelling seed traders and local hatcheries. Shrimp and prawn seed were obtained either from markets or, in the case of shrimp, were caught directly from the wild (this was the case only at Tangramary which was adjacent to the river channel and where seed collectors operated). According to respondents, fish seed were generally readily available but range of species available varied. The exception to this was in Bedemary where the reliability of seed availability (from seed traders) was considered a constraint. While seed was generally considered to be available, a number of respondents noted that seed quality was not always good and that it was not always possible to determine in advance the stocking mix, as this would depend on what was available.

Fish were generally stocked at a size of between five and ten centimetres. Where fish were sourced from the wild or collected as seed, they were usually smaller than this but were commonly grown on in nursery sections of the waterbody prior to release, for example in Jorria, Tangramary and Janakichak (see Plate 4). Brackishwater systems were therefore often stocked with smaller fish. It was widely recognised that the survival rates of the more advanced fingerlings were much greater than for smaller fingerlings. However, it was reported that a number of resource managers, particularly the poorer, were prepared to stock smaller fish seed as the fish seed were cheaper to purchase. In all cases those managing the system paid for stocking. However, at Pearypur the respondents indicated that the local village Panchayat provided a small subsidy, estimated at about INR 15000, towards seed and other costs.

**Plate 4 Stocking shrimp seed in the nursery section of a waterbody at Jorria. Note palm frond in the nursery area and cover for shade and protection from predators (Source: R. Arthur).**

In all cases farmers pursued a policy of polyculture. This is not unusual (e.g. WorldFish 2002, Kangmin 2001) though this stocking policy was adopted both to increase the production from the system as well as to spread the risk. The fish species that were reported during the appraisal as having been stocked included both indigenous and exotic species. Table 4 shows the species stocked in the waterbodies in 2003. Shrimp species were either penaeid species (primarily *P. monodon* and *P. indicus*) in the brackishwater systems. In freshwater systems the fresh water prawn *Macrobrachium rosenbergii* was stocked. The salinity of the water available had the greatest influence on the species that could be stocked and at Tangramary the majority of waterbodies were stocked with mullet because they were quite saline while the less saline waterbodies were also stocked with the Indian major carps. Indian major carps were commonly sold as a mix so the densities for these species are based on the approximate proportions of each in the mix and approximate number stocked.

**Table 4 Species of fish and shrimp stocked in the waterbodies together with approximate stocking densities and size at stocking in the cases where the species were stocked.**

| Site | Fish species stocked (bold type indicates exotic species) | Stocking density per hectare (size stocked (cm)) | Shrimp/prawn species stocked | Stocking density $ha^{-1}$ (size stocked (cm)) |
|---|---|---|---|---|
| Pearypur | *Labeo rohita*<br>*Catla catla*<br>*Cirrhinus mrigala*<br>*Labeo bata*<br>***Aristicthys nobilis*** | 3,750 (5-10)<br>1,875 (5-10)<br>1,875 (5-10)<br>170 – 500<br>350 (8-12) | | |
| Mohantiki | *Labeo rohita*<br>*Catla catla*<br>*Cirrhinus mrigala*<br>***Puntius javanicus***<br>***Ctenopharyngodon idella*** | 1,500 (5-10)<br>1,500 (5-10)<br>1,500 (5-10)<br>750 (5-10)<br>750 (5-10) | | |
| Kamardanga | *Labeo rohita*<br>*Catla catla*<br>*Cirrhinus mrigala*<br>*Labeo bata*<br>***Oreochromis niloticus***<br>***Cyprinus carpio***<br>***Hypothalmicthys molitrix***<br>***Aristicthys nobilis*** | 125 – 500 (5-7)<br>125 – 500 (5-7)<br>125 – 500 (5-7)<br>125 – 500<br>125 – 500 (3-5)<br>200 – 800 (5-7)<br>200 – 800 (5-7)<br>220 – 850 (5-7) | | |
| Janakichak | *Labeo rohita*<br>*Catla catla*<br>*Cirrhinus mrigala*<br>***Oreochromis mossambicus***<br>***Ctenopharyngodon idella***<br>***Cyprinus carpio***<br>***Hypothalmicthys molitrix***<br>***Puntius javanicus***<br>*Lates calcarifer* | 600 (10-12)<br>600 (10-12)<br>600 (10-12)<br>750 (3-5)<br>75 (10-15)<br>600 (3-5)<br>600 (3-5)<br>1,950 (3-5)<br>600 (3-5) | *Macrobrachium rosenbergii* | |
| Jorria | *Labeo rohita*<br>*Catla catla*<br>*Cirrhinus mrigala*<br>***Oreochromis mossambicus***<br>*Liza parsia* | 2,700 (5-10)<br>2,700 (5-10)<br>2,700 (5-10)<br>450 (2-5)<br>450 | Penaeid | 25,000 – 30,000 |
| Tangramary | *Labeo rohita*<br>*Catla catla*<br>*Cirrhinus mrigala*<br>***Oreochromis mossambicus***<br>*Lates calcarifer*<br>*Liza parsia*<br>*Mystus golio*<br>*Liza tade* | 1,600 (7-10)<br>2,400 (7-10)<br>2,400 (7-10)<br>3,000 – 10,000 (1-3)<br>750 – 2,000 (5)<br>10,000 – 60,000<br>4,000 – 60,000 (5)<br>400 – 8,000 | Penaeid<br>*Macrobrachium rosenbergii* | 10,000 – 80,000*<br>400 – 12,000 |
| Bedemary | *Labeo rohita*<br>*Catla catla*<br>*Cirrhinus mrigala*<br>***Oreochromis mossambicus*** | 1000 (3-5)<br>2000 (3-5)<br>2000 (3-5)<br>8000 (1-2) | | |

In Tangramary there were multiple stocking episodes, during the brackishwater period (approximately Jan-June) the shrimp stocking density was about half that of the freshwater period (June-Dec) stocking. In Tangramary the overall stocking densities of finfish appeared exceptionally high, though this may be a result of compensating for the stocking of smaller fish. It is often the case that where small fish are stocked it is the practice to stock larger numbers but the benefits from doing this as opposed to stocking fewer, larger fingerlings have been questioned (e.g. WorldFish 2002). In the other sites stocking densities were similar to those found elsewhere (e.g. WorldFish 2002, IIRR, 2000). The high densities may be an artefact of the questioning as the farmers placed low importance on the finfish component and were less inclined to monitor inputs and outcomes. Shrimp stocking densities also compare with elsewhere with Kumaran *et al*. (2003) reporting stocking densities for *P. monodon* in farms in Andhra Pradesh of 40,000 to 70,000 per hectare.

As can be seen from Table 4, the reported stocking densities and mixes were spatially variable. This is not unusual and has been also been reported for Southeast Asia (Demaine and Halwart 2001). When questioned about temporal variation, respondents indicated that while they would sometimes experiment with species and stocking densities, stocking was generally based on experience and knowledge exchanged with others managing similar systems. Recommendations from extension services were often incorporated into management but were appraised in the light of existing knowledge.

The main sources of variation in stocking density, apart from seed size, but especially where seed was sourced from the wild, were said to be availability and seed price. That ability to afford seed was a major factor in stocking densities is indicated by the higher stocking densities in the smaller waterbodies (Figure 2) and the responses of key informants when questioned about stocking strategies. This is by no means unusual and a similar situation has been described for both small waterbodies in northern Vietnam and Lao PDR and for reservoirs in Sri Lanka (Garaway *et al*. 2002, Nguyen *et al*. 2001, De Silva and Amarasinghe 1996). An additional consideration is that at higher stocking densities there is a need to supplement natural food in the waterbody through fertilisation and/or feeding. This increases the level of inputs and the additional costs may not be acceptable to resource-poor, risk-averse farmers (Demaine and Halwart 2001).

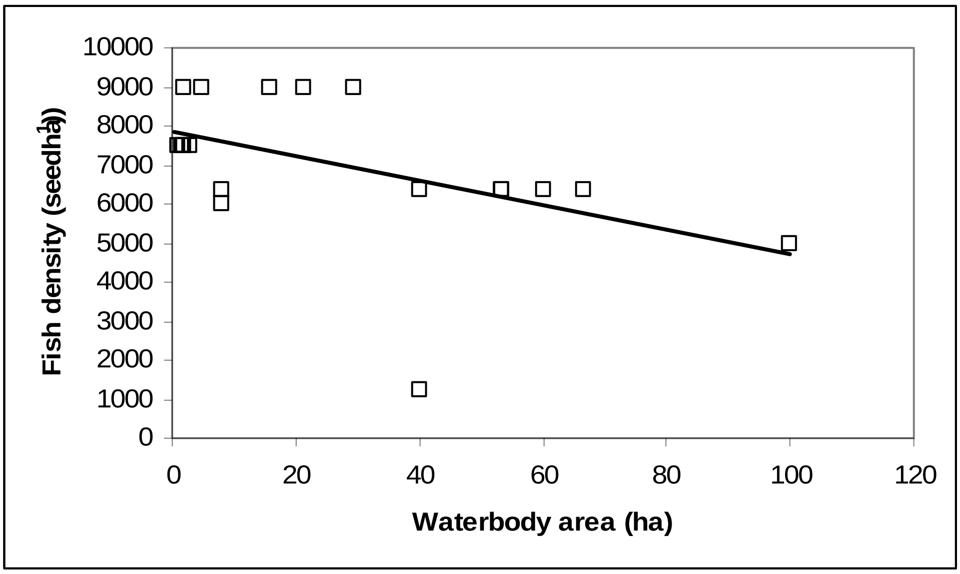



**Figure 2 Relationship between waterbody area and stocking density. Results for Tangramary have been omitted.**

As well as determining stocking density, environmental changes and market prices were also determinants of stocking mixes (see also section 3.4.3). The decreasing salinity (as noted in section 3.1) has been causing shifts away from the more saline tolerant species (e.g. *Liza* sp). In Janakichak the respondents indicated that changes in the pond environment meant that in recent years prawn (*M. rosenbergii*), beckti (*L. calcarifer*) and punti (*P. javanicus*) were performing less well. This has prompted a shift in the stocking strategy to include common carp (*C. carpio*) and silver carp (*H. molitrix)* that were more tolerant of the pond conditions. Because beckti can cause mortality in the prawn but has a high market value, there has been move to stock fewer prawn but maintain the beckti and punti. In the case of Tangramary, shrimp (for sale) was the primary crop and fish were stocked mainly as an insurance against the loss of the main crop. As such the stocking mix and densities of fish were quite variable and, because much was wild caught in this instance, very much linked to availability.

As mentioned, in the brackishwater areas there is a considerable dependence on this wild caught shrimp and fish seed, not just by the seed collectors but also those engaged in fish and shrimp culture. The Hooghly-Matlah estuary system is an important source of fish and shrimp seed with estimated annual shrimp (*P. monodon*) seed production in 1984 in the region of 190 million, out of an estimated requirement of 6,000 million for shrimp production in West Bengal (Mandal and Bhoumik 1984). Seed collection in the Sundarbans area of the Hooghly-Matlah alone is estimated to engage in the region of 400,000 people in collection activities (Bhaumik *et al*. 2002). These collectors, varying in age from 11 to 60 years in age, many of whom are women, are considered to be amongst the poorest groups in the rural population and the majority (approximately 70%) belong to the scheduled castes (Bhaumik *et al.* 2002). Collection is through the use of nets set along the banks of the estuary with catches vary through the year with highest catches in the period from February to May (see Plate 5). Within a given month catches will vary depending largely on the tides. Seed collected in this way are sold both directly to farmers and also to seed traders.

**Plate 5 Net set by the banks of the Icchamati river to collect Penaeid shrimp seed (Source: R. Arthur).**

Since the introduction of the Farakka Barrage, changes in the abundance and seasonality of shrimp and fish seed have been noted (De and Sinha 1997). It was found by De and Sinha (1997) that in the upper, less saline, reaches of the estuary Penaeid shrimps were no longer caught or were present in much lower numbers. It was also found that fish species associated with the more saline waters were available for a shorter period in these same areas. It was also noted by respondents in Jorria that during the collection of seed for the stocking of the waterbodies over 100 species of fish were caught but that these fish were discarded as by-catch, the majority not being returned to the water. This observation is supported by that of Bhoumik *et al.* (1993) who estimated that approximately 181.4 million unwanted fish and shellfish seed were destroyed during shrimp seed collection activities in one 40km stretch of the estuary alone between January and September 1992.

### *3.1.3 Effect of stocking on standing stocks*

Because of the limited nature of the appraisal and the timing, which did not allow for sampling of the water, plankton or fish it was not possible to determine either the effect of stocking on fish biomass or the contribution of wild fish to total waterbody biomass in any of the systems. However, all waterbodies were stocked on a regular basis and respondents indicated that the effect of stocking was to increase greatly the harvestable biomass. In systems where shrimp was a significant component, the biomass of fish was of secondary consideration. The results, such as they are, are similar to previous studies that have determined stocking can lead to higher standing stocks in a waterbody than in unstocked waterbodies (Arthur 2004, Lorenzen and Garaway 1997) and thus can increase the production potential of the waterbody.

## 3.2 Decision making arrangements

In examining the decision making arrangements associated with rice-fish culture systems it is important to understand the context in which decision making is occurring. This includes both the opportunities and constraints presented by the external arrangements as well as those inherent in the community. In addition to these, the types of rules arising from the decision-making arrangements are described.

Under the laws of West Bengal, ownership of land by individual farmers is recognised enabling individuals to manage the systems (where the biophysical attributes allow this) by themselves. This meant that commonly, though not exclusively, rice culture was conducted privately under individual management but the fisheries were subject to a variety of management regimes. However some government extension staff pointed out that management options were somewhat constrained by the Land Ceiling Act that meant that agricultural land could not be converted for fisheries purposes. This meant that some rice or other crop had to be grown on the land at some time and two crops of fish were not possible.

Where flooding creates a common pool resource any regulations created by the farmers as a group are fully recognised and they are entitled to enforce them. However, it is important to note that management rights exist, the active collective management of such waterbodies, including enhancement, is still minimal. It is much more common for management to consist of leasing the resource to an individual or group of individuals who then manage the fishery. Out of the total of 30 waterbodies surveyed, all had some form of rules in place governing access and/or use and these are discussed in more detail in Section 3.2.2.

Sources of information to inform decision-making included from other farmers, from State officials (from the Departments of Agriculture and Fisheries) and from their own experiences. Respondents reported regular contact with these State extension agencies at over half the sites visited. However in only one case (Mohantiki) was this the main source of information for management and Mohantiki was a site that had little experience with rice-fish culture. At all other sites experience was the most important factor followed by the experiences of other farmers. This is not unusual and it is often the case in small waterbody fisheries that management actions are based on the personal experiences and intuition of those managing them and many of the skills and knowledge about fish culture are acquired primarily through informal networks (e.g. Milwain *et al.* 2002, Lorenzen *et al.* 1998a). Advice from extension agencies was sometimes incorporated into management if it agreed with experience and in one case respondents indicated that they were not satisfied with the advice from these agencies. The level of contact is similar to that reported by

Kumaran *et al.* (2003) for similar systems though no indication is given by them of the source of management information.

### *3.2.1 Objectives of management*

In each village, the informants were asked about the primary objectives of their waterbody management. The results indicated that the primary objective of management was income generation and maximising the productivity of the land. As mentioned, in cases where shrimp was cultivated in brackishwater systems this was considered the main crop as it had the potential to generate the greatest income (see also section 3.4.3 regarding species preferences). This was the most important crop in these systems and respondents indicated that if they could get the technical knowledge they might move towards two crops per year. Whilst this result may have been partly influenced by the initial site selection (extension officers may be more aware of management initiatives geared towards maximising revenue than others), the extension officers were encouraged to provide as full a census as possible of rice-fish in their districts. It is believed therefore that, as suggested in previous research elsewhere (e.g. Garaway 1999), income generation can be a major catalyst for more active management.

It is interesting to note that fish for household consumption was not rated as a high priority in any of the sites visited. Fish is an important part of the diet for households in West Bengal with fish consumption of freshwater fish amongst the highest in the world (Little *et al*. 2002). The inundated paddy plots in the deepwater systems and those where fish were present along with the rice have been identified a useful source of fish (in particular wild fish) for the individual landowners for household consumption. This observation has also been made by both Baruah *et al*. (1999) and Das *et al*. (1993) for rice-fish systems in West Bengal and Assam respectively. It was however found that in the majority of cases, households had other resources available to them as a source of fish and the amount of fish caught from the rice paddies was relatively small compared to that from other sources. This was a small pond (tank) typically in the order of 0.1-0.8 ha and located near the house (see Plate 6). These tanks were stocked annually, usually with Indian major carps. The tank was therefore able to provide fish to a household or small number of households (3-4 poorer households might share a single tank). In occasional cases where some *M. rosenbergii* had been stocked as well the tank could also provide a small household income.

**Plate 6 Example of a small household tank providing fish for household consumption, Tangramary village (Source: R. Arthur).**

The household tanks were also used as a source of water for livestock, and for washing and bathing. Drinking water and water for cooking was more usually sourced from wells. As a result, the rice-fish system was not depended upon as a source of fish for the household. In cases where households did not have access to such tanks (as was the case in Kamardanga village, predominantly a *Ghosh* caste village), there was a much greater reliance on fish bought at the market. The source of fish for households as described by the informants is shown in Table 5. As this shows, the main source of fish varies essentially with wealth. It was also the case that fishers were regarded as amongst the poorest groups within the community and this is reflected in the sources of fish, which more closely resemble that of the landless.

**Table 5 Typical sources of fish for household consumption for different sectors of rural communities in West Bengal.**

| Sector of community | Source of fish for consumption (%) | | |
|---|---|---|---|
| | Tank | Market | Wild caught |
| Landowner | 20 | 70 | 10 |
| Fishers | 5 | 5 | 90 |
| Landless* | 5 | 0 | 95 |

*This category excludes those explicitly described as fishers although fishers also often had little or no land

The types of management regime employed in the rice fish systems for income generation are discussed in the following section.

### *3.2.2 Management regimes*

The types of management encountered in the appraisal could be broadly categorised either as private ownership, rental or collective fishing systems. In all a total of four different management systems were identified (see Table 5). In a number of cases the biophysical aspects of the system meant that while rice culture by individual farmers was possible, the common pool nature of the inundated resource meant that fish culture had to be organised on a group basis. This type of rice-fish management has also been noted in Bangladesh (e.g. Reshad Alam *et al*. 2001, WorldFish 2002). It is interesting to note that no examples of collective fish culture in brackishwater systems were encountered, systems that require heavy investment and a willingness to take risks in order to maximise the benefits from the system.

**Table 6 Management categories for rice-fish culture waterbodies.**

| **Description of management** | **Fisheries management category** | **Freshwater systems** | **Brackishwater systems** |
|---|---|---|---|
| Individual rice culture, group fish culture in inundated area. | Collective | Kamardanga | |
| Group rice culture, group fish culture in inundated area. | Private | Pearypur, Mohantiki | |
| Individual rice culture, inundated area leased for fish culture. | Leasing | Kamardanga, Janakichak | Jorria |
| Individual rice culture, individual fish culture in inundated area. | Private | | Tangramaray, Bedemary |

It should be noted that the Table 6 is not exhaustive and indicates the management of resource systems at the sites visited.

<u>Private management</u>

In this case Private refers to systems where both the rice and the fish culture are carried out by the same entity. This could be a single household or number of closely affiliated households as at Tangramaray and Bedemary or, alternatively, a cooperative arrangement where a group of individuals have collectively invested in the system as at Pearypur and Mohantiki. Private management by individuals was found in association with smaller, enclosable areas that had access to water and where the landowner had the resources to be able to stock, monitor and harvest. In both Pearypur and Mohantiki the management groups had good access to financial resources and in the case of Pearypur this meant that they had been able to create an intensive culture system with a high level of inputs. At both of these sites external labour was used for harvesting. In Tangramaray and Bedemary by contrast, the households involved were financially poor but had access to shrimp and fish seed from the nearby estuary enabling them to be able to manage themselves. At both of these sites the households involved were from a fishing caste and carried out all activities from stocking to harvesting.

#### 3.2.2.1 Collective management

In these systems management is characterised by individual culture of rice followed by group fish culture (Table 6). This is similar to the systems described by WorldFish (2002) in Bangladesh. This collective management was found in association with larger waterbodies where individual private management was not possible. These systems were uncommon and this is perhaps a reflection of the difficulty in creating the necessary management institutions and the risks to the individual who must invest in the system for an uncertain return. In this system, the waterbody would be stocked in June/July by the management group and at the end of the culture period the group would arrange the marketing and hire fishers to undertake fishing.

#### 3.2.2.2 Rental systems

Rental, or leasing, systems were quite common both in the larger freshwater systems and especially in the brackishwater systems. Renting involved the leasing of the waterbody for all or part of the year[3] for a fixed sum. The waterbody was rented an individual or group of individuals, sometimes, in the larger systems, from within the group of landowners renting out the waterbody. The number of landowners varied from site to site visited with between 20 (Jorria) and 300 (Jorria) with individual land holdings varying from 0.09 to 0.22 ha. This represents a low average landholding compared to the state average estimated in 1995 at 0.85 ha (Bardan Roy *et al*. 2001). The waterbodies are put up for rent and the best offer secures the rights to fish culture. The renters then have exclusive management rights for the culture period and can exclude all, including the landowner, from the system, prohibiting even the collection of fish or other aquatic organisms for subsistence purposes. It is the responsibility of the renters to arrange the stocking, monitoring and harvesting of the system. Where the waterbody was under the jurisdiction of a group of landowners, the income from the renting would be shared amongst the landowners on the basis of the amount of land held (e.g. Jorria).

---

[3] In the more productive brackishwater systems where high value Penaeid shrimp could be cultured, e.g. in South 24 Parganas, it was common for the waterbody to be leased out year round for shrimp culture allowing the individual or group leasing the waterbody to cultivate shrimp crops in both the dry and monsoon seasons at the expense of rice.

In all the systems studied, the rules put in place and the resulting restrictions could be seen to account not only for the objectives of those managing the resource but also the socio-economic characteristics of the site at which it was located and the biophysical attributes of the resource. Together this accounts for the variety of management seen in Table 6.

## 3.3 Patterns of interaction

The patterns of interaction effectively describe the monitoring, enforcement and fishing activities in the resource systems. All the waterbodies in the study had some form of formal or informal monitoring in place to prevent illegal fishing. Monitoring and enforcement was the responsibility of those managing the system and in larger systems individuals would be employed and paid a wage in return for this service. The type of monitoring system varied primarily with the size of the waterbody. In Tangramary and Bedemary, where the waterbodies were small, privately owned by individual households and located near to the house, it was the household that would monitor the waterbody. In larger resource systems such as those at Jorria, Janakichak and Pearypur the system was more organised and there would be guardhouses established by the waterbodies that were equipped with drums in order to raise the alarm and boats used to patrol at night (see Plate 7). In addition, it was expected that villagers would monitor the waterbody during their daily activities and report infringements. Respondents indicated that illegal fishing, together with poisoning was an important threat to successful management and that such activities were fairly widespread. If caught a transgressor might be dealt with severely at the hand of those monitoring the waterbody.

**Plate 7 Guard hut and boat used for patrolling the waterbody (submerged) at the Jorria site (Source: R. Arthur).**

Harvesting of the freshwater systems was generally conducted between November and December. For the brackishwater systems that rely upon the monsoon rains to desalinate the soils prior to rice cultivation (e.g. Jorria) the harvesting period was around May. In both cases harvesting occurred after a culture period of around 120 days. The pattern and duration of fishing in the waterbodies was similar in all systems and the major variable was the size of the waterbody and ease of draining. All systems were harvested through intensive fishing together with pumping or draining of the waterbody which could be all on one day or over a number of days depending upon demand for fish. Often fishing would start very early in the morning as the price of fish would decrease over the day.

Harvesting in the larger systems conducted by labourers, often landless, from the lower fishing castes who traditionally dominate fish catching and handling (also reported by Little *et al*. 2002). These individuals, often from nearby but also migrant labourers from the Sunderbans region, both male and female, would be paid in cash and/or fish for their labour. As such the rice fish systems represent a significant source of income for these people (see also WorldFish 2002). The harvested fish were generally either sold to visiting fish traders (e.g. Pearypur) or taken for auction at the local market (e.g. Jorria and Mohantiki).

## 3.4 Outcomes

Labour has often been found to be the highest cost in rice-fish systems with fertiliser and irrigation (where applicable) the next most important (WorldFish 2002). In terms of the fishery, shrimp seed was a major expense, together with fertilisation and feeding (where applicable). As mentioned, in the majority of the sites, particularly the larger ones, members of low or scheduled castes conducted the harvesting of the fishery. These people are among the poorest in the communities and the income provided from the rice-fish systems was an important contribution to household income.

### *3.4.1 Yields and income from the fisheries*

For the analysis the results from the appraisal were combined with data from other studies including Mohanty *et al.* (2004), WorldFish (2002) and IIRR (2000), (see Table 7). This provided a larger data set that could be examined in more detail to determine some of the factors affecting yields from the rice-fish systems.

**Table 7 Details of the additional data sets included in the analysis including number of waterbodies and types of cultured organisms.**

| Study | System | Waterbodies | Fish | Shrimp | Culture period (days) |
|---|---|---|---|---|---|
| WorldFish (2002) | Deepwater | 8 | ✓ | | 120-175 |
| IIRR (2000) | Deepwater | 11 | ✓ | ✓ | 104-168 |
| Mohanty *et al.* (2004) | Rice paddy | 9 | ✓ | ✓ | 120 |

In the analysis, logarithmic transformations were applied to all variables prior to regression analysis as many varied over an order of magnitude and showed visible heteroscedasticity. Where only lengths of seed at stocking were available these were converted to weight using length-weight conversions based on the data (see Appendix 2). Yield predictive models were derived through the application of linear and quadratic regression analysis to the transformed variables. Because of the varied nature of the data set and limited nature of the appraisal, it was not possible to include biophysical variables such as productivity or a comprehensive range of management factors in the analysis.

3.4.1.1 Brackishwater systems

While no estimates of shrimp yield from the shrimp only culture could be obtained, Kumeran *et al.* (2003) have reported for similar systems that dry season crop was between 800 and 2,000 kgha$^{-1}$ while during the monsoon season this was both lower (500 to 1,000 kgha$^{-1}$) and more uncertain. It has also been noted that while the shrimp are the principal crop, wild fish can often make an important contribution to the catches in these fisheries (Reshad Alam *et al.* 2001).

In the systems that were culturing shrimp/prawn with fish, shrimp and prawn yield estimates ranged from 40kgha$^{-1}$ to 350kgha$^{-1}$. Unfortunately data for both stocking and yields were only available for the privately managed fisheries in Tangramary. At this site stocking densities of Penaeid shrimps in 2003 ranged from 10,000 to 80,000 (median = 37,500) ha$^{-1}$ and *M. rosenbergii* from 0 to 12,000 (median = 3,350) ha$^{-1}$. The data was explored using regression models to investigate the relationships between variables including stocking density and the density of additional fish stocked. This indicated that there was a strong positive correlation only between shrimp/prawn stocking density and yield for shrimp and prawn (Figure 3) with all parameters significant at P<0.05. Details of the model fitted are:

$$\ln Yield = 0.896(0.165)\ln SD - 4.416(1.74)$$

$R^2 = 0.787$; n = 10; $P<0.05$

Where Yield is the combined yield of shrimp and prawn in $kgha^{-1}$ and SD is the stocking density of mixed Penaeid and *M. rosenbergii* seed per hectare. Figures in brackets are the standard deviations of the parameter values.

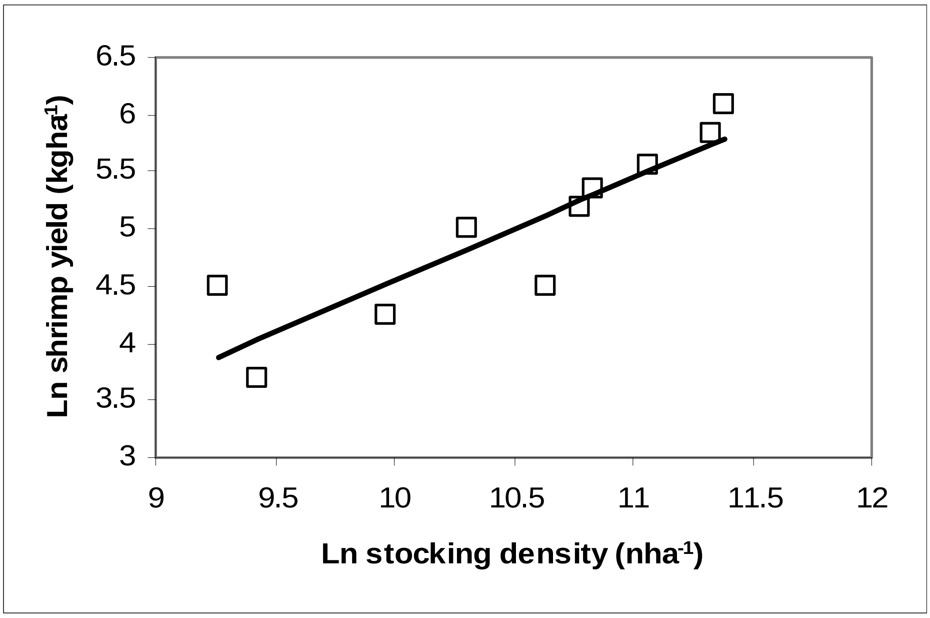
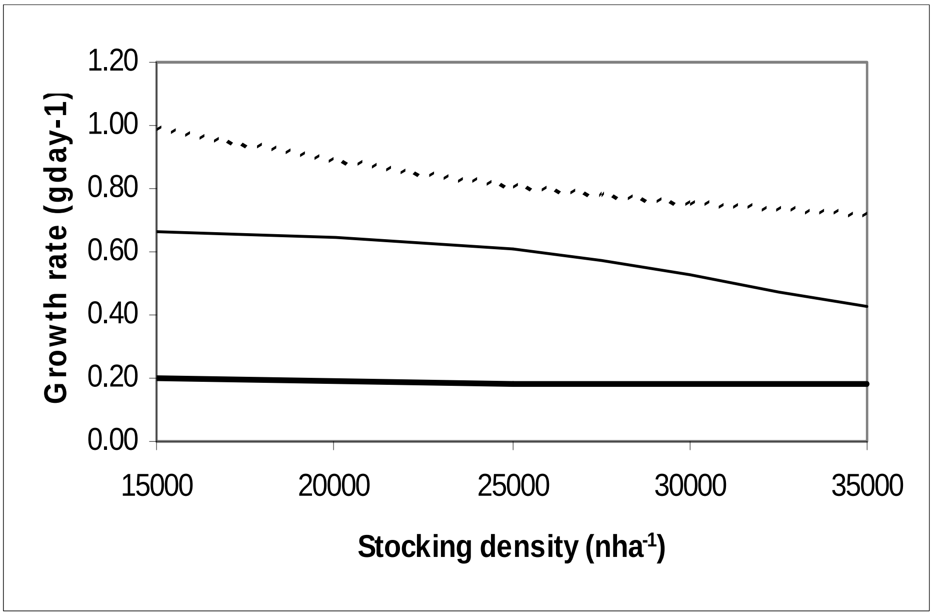
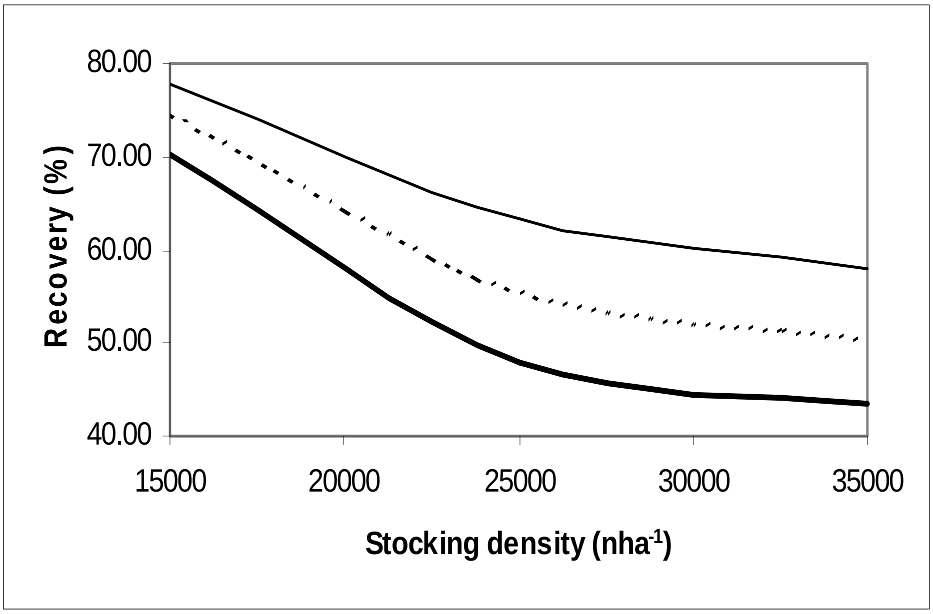



**Figure 3 Effect of shrimp stocking density on shrimp yields in the Privately managed waterbodies in Tangramary.**

Data from the study into stocking in freshwater rice paddies by Mohanty *et al*. (2004) that included *M. rosenbergii* were explored and these suggested that at densities between 15,000 and 35,000 $ha^{-1}$ while there was little negative effect on growth, especially compared to the fish species stocked, recovery rates were lower at higher densities, although these seem to be levelling out (Figure 4). This suggests some density dependent effect that might be expected to limit yields at higher densities. However, in the data from Tangramary there was no evidence of this, although the data may not be accurate enough to show this or the effects may be low at these densities.




a)




b)

**Figure 4 Results from a study by Mohanty *et al*. (2004) showing the effect of stocking density on growth (a) and recovery rates (b) of *M. rosenbergii* (thick line), *L. rohita* (thin line) and *C. catla* (dotted line).**

It has also been found that in brackishwater systems where there is fish culture followed by Kharif rice culture after the monsoon rains, the fish culture does not adversely affect the rice yields unless the monsoon rains are insufficient to desalinate the soils (Bardan Roy *et al.* 2001, Ghosh *et al.* 1985).

### 3.4.1.2 Freshwater systems

There was more data available for the freshwater systems allowing a more detailed investigation into factors affecting yields from these fisheries. Total stocking densities in the combined data ranged from 5,500 to 35,000 $ha^{-1}$ (median = 10,000 $ha^{-1}$). All the systems included were managed as polyculture systems containing Indian carps (*L. rohita, C. mrigala* and *C. catla*) together with other species including common carp, *P. javanicus* and *M. rosenbergii*. The culture period varied from 104 to 168 days (median = 125 days). The size of fish seed size at stocking also varied from 0.04 g up to 50.1 g (median = 13 g) and there were some differences in culture practice with a number of the systems being given feed. Initial analysis indicated that yield (*lnYield*) was unrelated to the culture period (*lnDays*). It might be assumed that the length of culture, and opportunity for additional weight gain, would have a significant effect but while it was positively correlated, the effect was not significant. Significant positive correlations were found between *lnYield* and total stocking density (*lnSD*) and *lnYield* and the size of fish seed stocked (*lnSeed*). The relationship between *lnYield* and *lnSeed* is illustrated below in Figure 5.

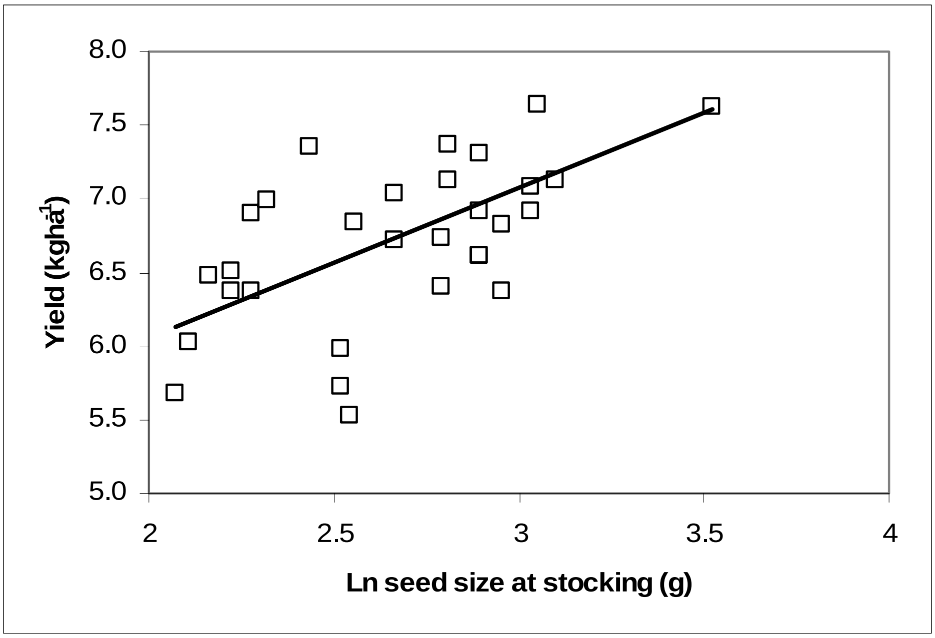



**Figure 5 Effect of the size of fish seed stocked on yield from the fishery. Line represents Model 3 in Table 8.**

Single and multiple regression models to predict *lnYield* from the variables *lnSeed, lnDays* and *lnSD* together with a dummy variable representing whether there had been feeding or not were developed and those for which the variables were significant (P<0.1) are given in Table 8. In both the single and multiple regression models only linear terms for *lnSD* and *lnSeed* were significant (P<0.05).

**Table 8 Yield predictive models for the fishery component of rice-fish systems. Standard deviation of the parameter estimates provided in brackets.**

| |
|---|
| Variables:<br>Y: Total yield from the fishery (kgha-1)<br>SD: Total stocking density (nha-1)<br>Seed: Average size of the seed stocked (g) |
| Models:<br><br>Model 1: Yield from stocking density<br>$LnYield = 1.140(2.769) + 0.609(0.300)LnSD$<br>$R^2$ = 0.105; n = 37; P <0.05<br><br>Model 2: Yield from stocking density<br>$LnYield = 1.274(2.631) + 0.121(0.057)LnSD + 0.243(0.114)SD^2$<br>$R^2$ = 0.123; n = 37; P <0.129<br><br>Model 3: Yield from seed size<br>$LnYield = 3.788(0.697) + 1.101(0.260)LnSeed$<br>$R^2$ = 0.428; n = 34; P <0.05<br><br>Model 4: Yield from stocking density and seed size<br>$LnYield = 1.438(0.337)LnSD + 0.441(0.124)LnSeed - 7.556(3.327$<br>$R^2$ = 0.378; n = 34; P <0.05 |

In the initial analysis neither culture period nor feed appeared as significant variables. This may well be because the effect of the seed size and stocking density were that much larger. In order to investigate the effect of the culture period, a subset of the data set was selected that had similar seed size (10 +/- 2 g). A regression model was then used to examine the relationship between *LnDays* and the Yield per seed fish (*LnYPS*). As can be seen from the model below and Figure 6, and as might be expected, there was a positive relationship with culture period when other factors were accounted for. Details of the model fitted are:

$$\ln YPS = 2.701(0.620)\ln Days - 15.988(3.043)$$

$R^2$ = 0.678; n = 11; P<0.05

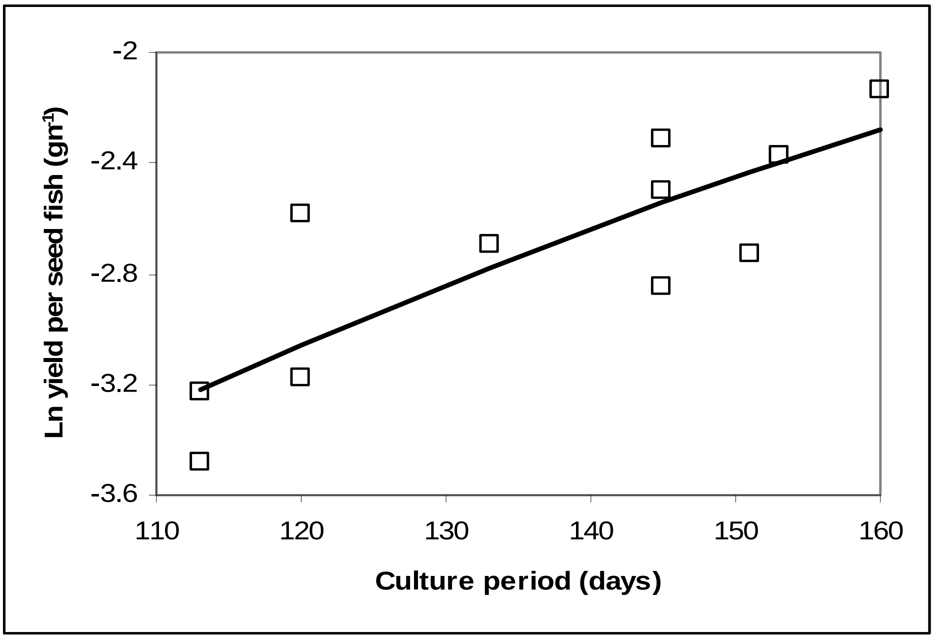



**Figure 6 Predicted yield per seed fish as a function of culture period for seed of similar size.**

The growth rates of the individual species stocked are shown in Figure 7. Grass carp was rarely stocked and where it was it was at large seed size, thus accounting for both the high growth rate and wide confidence interval. Of the remainder it can be seen that *C. carpio* and *C. catla* both had high growth rates while of the finfish, *L. rohita, C. mrigala* and *P. javanicus* were the poorest across the waterbodies. The prawn *M. rosenbergii* was found to have the lowest growth rate and respondents indicated that *P. monodon* also had a low growth rate. In Jorria the respondents also described the growth of *P. monodon* in their systems as being highly variable.

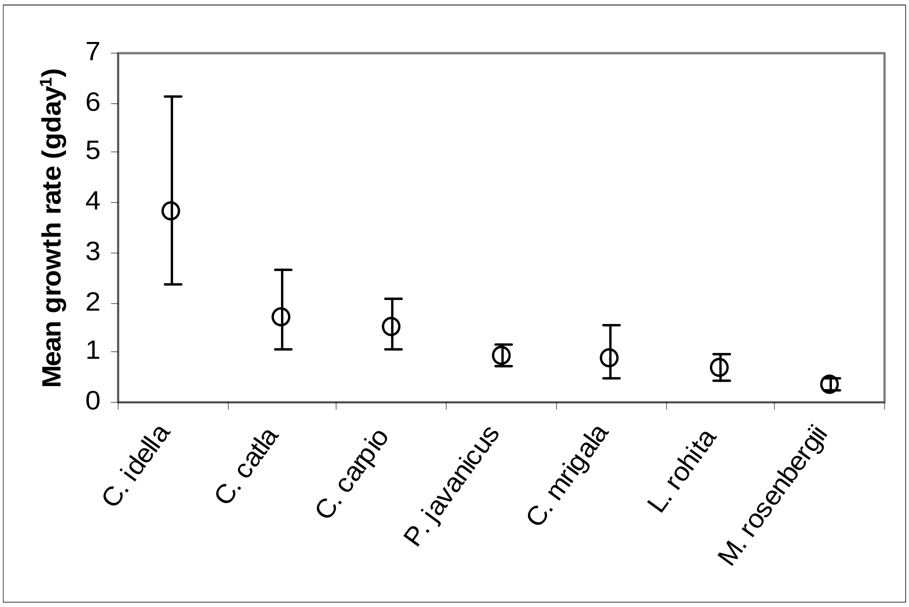



**Figure 7 Mean daily growth rate for the most commonly stocked species. Bars represent the 95% confidence interval of the back transformed mean.**

Yield per seed fish shows a similar picture to the growth but is based on a combination of the stocking density and the recovery rate (Figure 8). It can be seen that *P. javanicus* performed least well of all the finfish and *C. carpio* and *C. catla* the best. This result could have implications for managers of systems who wish to maximise their return on fish stocked, i.e. to maximise production. In systems where small fish were stocked mortality due to predation, for example by birds, frogs and fish was believed to be very high and in Bedemary was reported at around 90%.

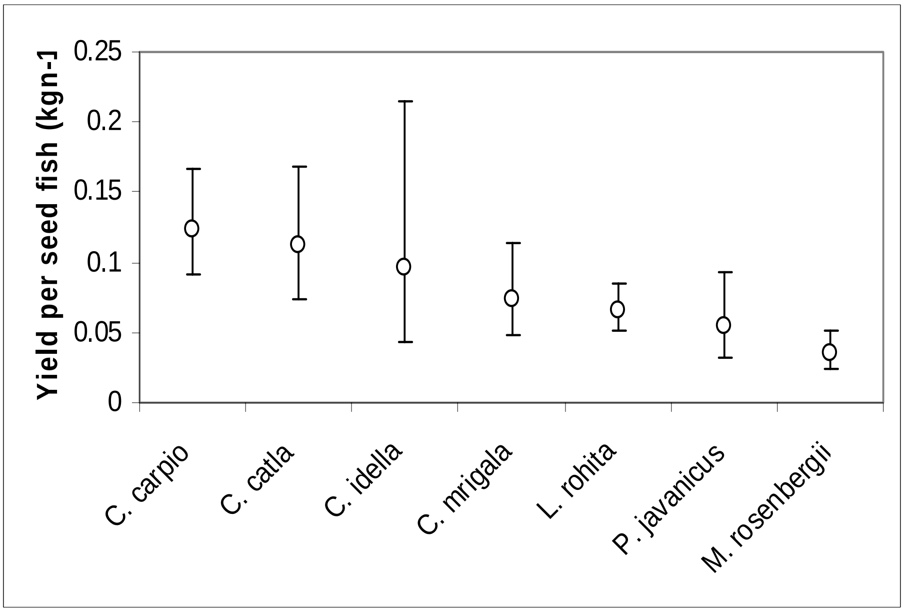



**Figure 8 Mean yield per seed fish for the most commonly stocked species. Bars represent the 95% confidence interval of the back transformed mean.**

The predicted yield as a function of the seed size stocked and the stocking density (Model 4 in Table 8) is shown in Figure 9. The highest yields are at the highest stocking densities and seed sizes.

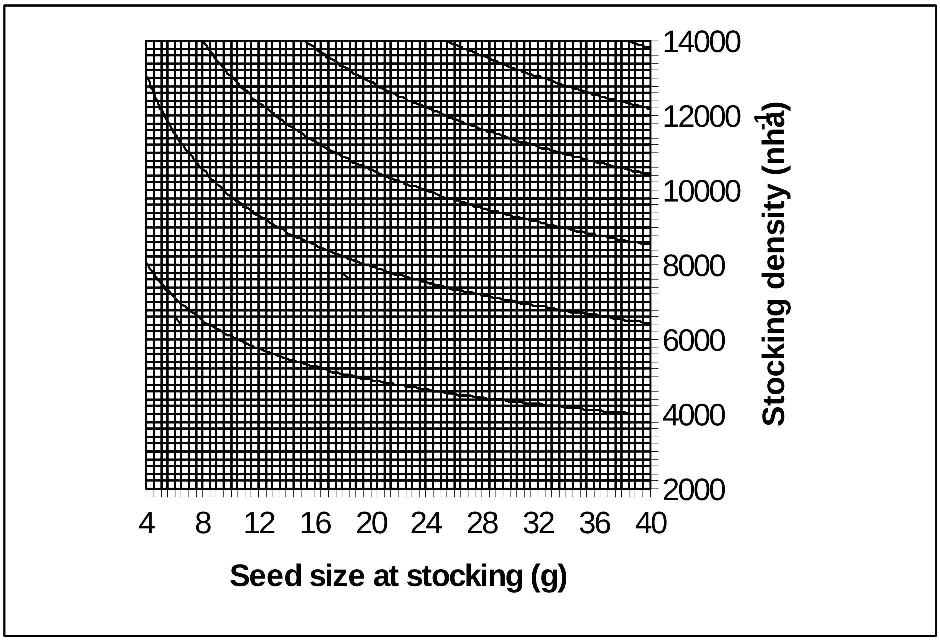



**Figure 9 Predicted yield as a function of size at stocking and stocking density. From the bottom, the solid lines indicate potential yields of 400kgha$^{-1}$, 800kgha$^{-1}$, 1000 kgha$^{-1}$, 1200 kgha$^{-1}$ and 1400 kgha$^{-1}$ respectively.**

The predictive yield model suggests that increasing the seed size at lower seed sizes can have a large effect on yields (most probably through increased survival) while at larger seed sizes the stocking density can have more of an effect on the yield. This may have implications in a trade-off between buying larger seed (which are more expensive) and spending the money on increasing the number of fish stocked. In this respect, WorldFish (2002) have noted that farmers recognise that mortality rates for smaller fish are higher and so tend to buy more to compensate but that this did not necessarily lead to a better outcome. However their study was based on stocking of finfish only.

In order to investigate the trade-off between seed size and stocking density further only the data relating to finfish seed were considered. Based on the available data and information on fingerling and fish prices collected during the appraisal it was possible to construct a simple bio-economic model to provide an initial insight into this trade-off. Finfish fingerling price had been suggested at between 0.25 and 1 rupee (INR) per seed depending upon the size, while the price of fish also varied between 20 INR and 70 INR per kilogram for the species stocked (while the appraisal has focussed on systems harvesting in November/December, it has been suggested, e.g. by FAO 2001, that fish prices remain fairly constant year round). The model is based only on these economic variables together with the a model for finfish yield with the following form:

$$LnYfish = 0.871(0.193)LnSD + 0.816(0.222)LnSeed - 3.235(1.997)$$

$R^2 = 0.571$; n = 34; P <0.05

Seed cost per seed in INR was based on the information collected, providing a function of seed size:

$$SeedCost = 0.102 Seedweight - 0.6$$

In addition, it was known that the price of fish varied with size, larger fish having a higher value than smaller. Stocking either small fish initially, or at high densities can affect the individual size at harvest. To account for this, fish price was assumed to be a function of both stocking density and initial seed size according to the function:

$$Fishvalue = 1.100 Seedweight - 0.001 SD + 31$$

It was also assumed that costs associated with monitoring and harvesting would remain relatively fixed while feed costs are assumed to be proportional to stocking density so that these could be left out when considering the effect of density and fish size. All of these assumptions should be further tested but the model should at least provide some initial insight.

The net income, i.e. the revenue from finfish sales minus the cost of stocking for a range of finfish seed sizes and stocking densities is shown in Figure 10. As this shows, it would appear that greater gains in net income might be achieved by increasing the size at which fish are stocked rather than investing in higher fish stocking densities. At higher stocking densities, i.e. in more intensive systems, this effect is greater and increasing the size of seed stocked can provide much greater returns. The model would seem to suggest that increasing stocking densities to compensate for smaller seed size is not the best option compared to increasing size at stocking and may explain why no significant increase in benefits from this strategy could be detected in the study by WorldFish (2002).

It should be stressed that this model can only provide preliminary insights and would benefit greatly from improved parameterisation and further testing of some of the assumptions on which it is based.

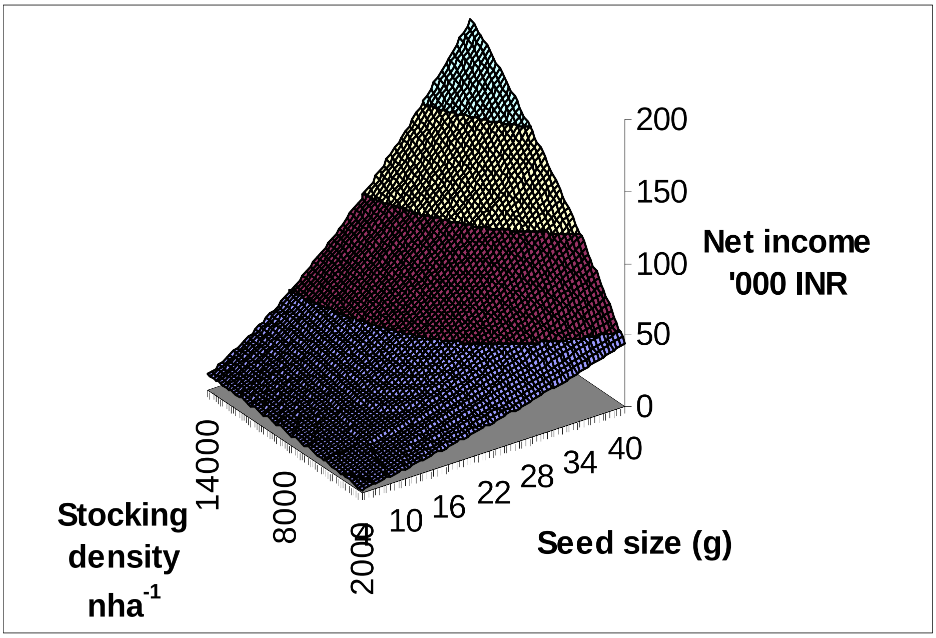



**Figure 10 Net income in Indian rupees per hectare (INRha$^{-1}$) for finfish only as a function of stocking density and seed size based on a simple bio-economic model (see text for details). Bands represent incomes in INR per hectare of 0-50, 50-100, 100-150 and 150-200.**

It was found that the income generated from fish culture in the rice-fish systems was very significant when compared to other income generating sources including rice cultivation (Bardan Roy *et al.* 2001). This was particularly the case where shrimp was cultured as this is a very high value product, and the principal reason that it was stocked despite the low production (Figures 7 and 8).

As mentioned, the stocking strategies at each site were dependent on the biophysical characteristics of the resource system and were mainly informed by experience. However the market price was also a crucial factor (see also section 3.4.3) and species with poor growth were stocked where demand and the market price were high. Average price of fish from sites visited in the appraisal is shown below in Table 9. As can be seen, and as has been noted in a number of other studies, wild fish species such as *L. calcarifer* and *Mystus* sp. have a higher market price than many of the cultured species.

**Table 9 Mean fish price by species from the results of the appraisal.**

| Species | Mean price ($INRkg^{-1}$) | Standard Error of the mean |
|---|---|---|
| *P. monodon / M. rosenbergii* | 220 | 35.1 |
| *L. calcarifer* | 105 | 22.2 |
| *Mystus* sp. | 75 | 45 |
| *Liza* sp. | 62.5 | 37.5 |
| *O. niloticus* | 55 | 2.9 |
| *P. javanicus* | 50 | 5.8 |
| *L. bata* | 40 | 13.5 |
| *C. catla* | 37.8 | 5.6 |
| *L. rohu* | 37.3 | 5.2 |
| *C. mrigala* | 33.9 | 4.7 |
| *C. idella* | 33.3 | 3.3 |
| *H. molitrix* | 27.5 | 3.2 |
| *A. nobilis* | 18.4 | 4.7 |
| *C. carpio* | 17.5 | 5.9 |

Income generated by the fishery differed by management category. In the case of the private management, the entire benefits from production accrue to the individual; in collective management the individual receives a share of the benefits from the fish production while in the rental system the landowner receives only the rental (or a share of the rental price). When it came to income generated by management system category it was found that respondents generally perceived that managing a waterbody by private management or, where that was not possible because of the biophysical attributes, organising collective management could potentially provide the highest level of income and other benefits such as fish for consumption for those involved. Private management by a cooperative, such as at Pearypur and Mohantiki, was interesting as a comparison with collective management as it seemed that management by the cooperatives was less difficult in terms of decision making and implementing management actions. Possible reasons for this include the fact that these groups had good access to financial resources and the people involved were like-minded entrepreneurs who had a good level of education and who were also willing, and who could afford, to take risks in investing in the fishery. While these systems, and in particular the system in Pearypur, did not meet the criteria for inclusion in the study, it may be interesting to undertake further investigation into the differences between these cooperatives and the collective management systems and the criteria for successful co-management suggested by Pomeroy *et al*. (2001) might be useful in this respect.

Despite this, rental systems were widespread and the reasons given for this included the difficulty in organising individuals and creating appropriate management institutions, the risk-averse nature of many of the poor farmers and, particularly in the case of shrimp culture, the prohibitive costs of inputs such as seed and feed (estimated by Bardan Roy *et al*. (2001) to be at least ten times the cost of a second rice crop). While the benefits received were potentially not as much as Private or collective management, in terms of income it has still been found to be substantial. Compared to a single crop of rice, renting provided an income that was eight times greater and over four times the income from cultivating an additional crop of rice, where this is possible (Bardan Roy *et al*. 2001). Where landowners were conducting shrimp culture it was commonly in areas where there was direct access to seed from the wild allowing the landowner to effectively reduce the costs of inputs. Rental systems were considered attractive in that it was a relatively simple system with a guaranteed income provided up front. The risk (and additional benefits) was taken by the renter. However, in some areas, particularly the brackishwater areas, the prohibitive costs of culture meant that the poorer landowners felt that they had little option but to rent and that the rental price they were receiving was low considering the benefits that would accrue to the renter. However, Bardan Roy *et al*. (2001) also found that where renting was carried out over a number of years, the landowner would observe and learn the culture practices from the renter and then try by themselves.

Respondents indicated that he income from rental systems depended upon the biophysical characteristics of the waterbody including the area, depth and productivity. In areas where there were many waterbodies available for rent, such as around Jorria, South 24 Parganas and Janakichak there were some fairly accepted rates. For example, in Janakichak, a freshwater culture area, the going rental rate for a shared waterbody, depending upon waterbody depth and area, was in the region of 7,500 to 12,000 INR per hectare. In the brackishwater areas around Jorria, similar shared waterbodies were rented for between 22,000 up to 60,000 INR per hectare. The price depending upon the productivity of the waterbody and the area.

### *3.4.2 Factors affecting outcomes of rice-fish management*

As can be seen, although the waterbodies were managed with the same overall objective of generating income, the actual outcomes of the management process were quite different depending upon a number of factors both biophysical and also institutional. From the available information it is possible to construct a simple model that describes the potential options for management and land use during the dry season. When discussing land use it is assumed that the land is already used for a single crop of rice during the monsoon period.

The biophysical characteristics, in particular high salinity and control of water, together with access to resources are considered to be the main factors affecting management. It is important to clarify these terms to avoid confusion. In this case they are taken to mean the following:

- Salinity here refers to the water salinity.
- Control of water refers to a combination of access to water and an ability to retain and/or regulate water supply. The latter is considered to be as important as access.

- Access to resources is more complicated but is taken to mean access to any of a range of resources such as financial credit, capital, seed availability and, where available and in addition to at least one of these, access to technical and market information.

These factors can combine to determine to an extent the potential of the land for rice-fish culture system of management that could be established and the potential outcomes. While it is recognised that productivity will be a factor that affects the outcome of management it is suggested that this is less likely to be a factor that determines the land use and management options. How the three factors identified above combine to affect land use and options for fisheries management is illustrated below in Figure 11.

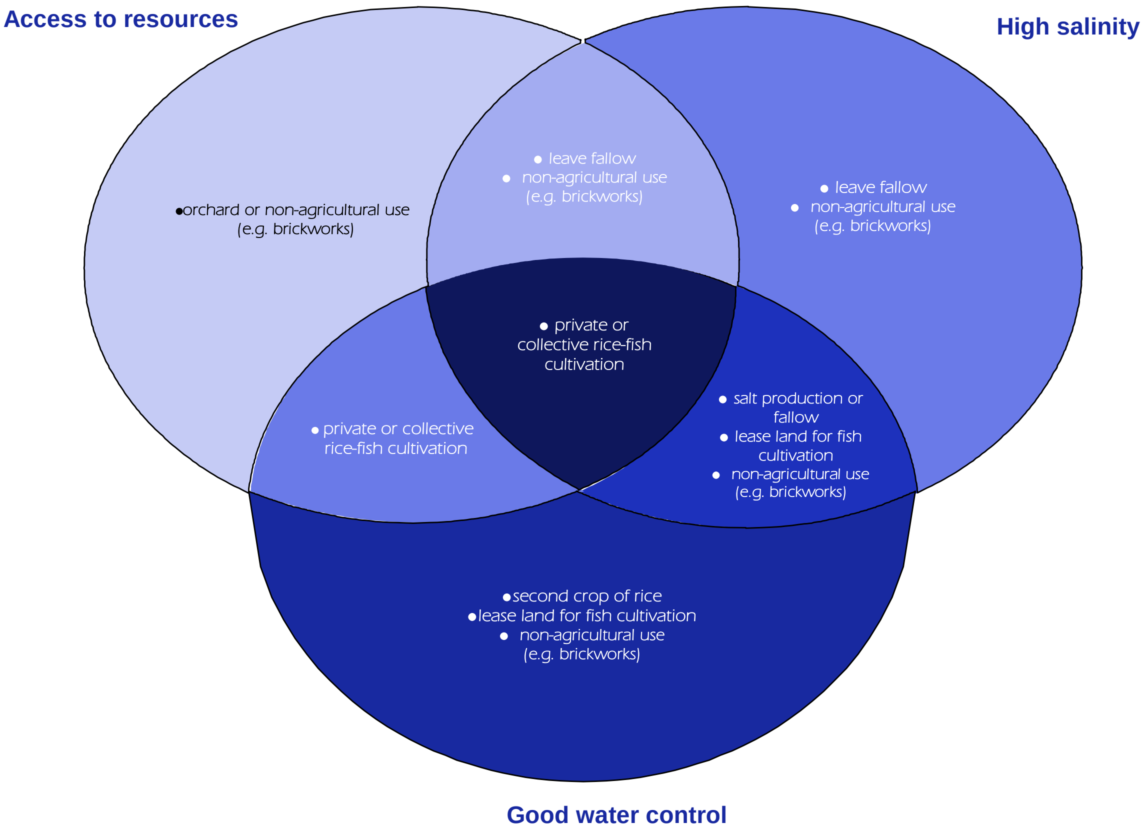



**Figure 11 Factors affecting land use decisions and the choice of management system in rice-fish systems in West Bengal.**

In support of the proposed model, Bardan Roy *et al*. (2001) suggested that salinity is the most important variable affecting land use and the uptake of fish culture. Where saline water is available they suggest that fish culture will be pursued, probably due to the potential returns from shrimp culture. Water controllability is also mentioned by both Bardan Roy *et al*. (2001) and Chakraborti and Bhowmik (1985) as a factor that is important in fresh and brackishwater systems in determining whether the land is left fallow, used for a second rice crop or for fish culture. Visits to sites during the appraisal also illustrated that this was a key factor. Access to resources was a crucial factor affecting management in brackishwater areas. Seed price meant that in the more brackish areas farmers couldn’t culture shrimp privately (unless a very small area and there was access to seed, e.g. Tangramaray) or collectively and fish culture, because of the lower market price compared to shrimp, yielded lower revenues at higher risk than leasing to a group or wealthy individual for shrimp culture.

While in the model it is suggested that where private management is possible collective management is also an option. This will essentially depend upon the nature, and in particular the size relative to land holding. Where flooding leads to the inundation of areas far greater than an individuals holding (typically in the region of 0.2 – 0.5 hectares) and thereby resulting in a common property resource, private management is not possible and in such cases management would either be through collective management (e.g. Kamardanga) or, more likely, renting of the system. Where an individual (or group of individuals) has sufficient access to resources, it may be possible for them to enclose an area of the resource, e.g. through a pen or cage and manage privately within this. However, no examples of this were encountered during the appraisal and it is thought that, having access to resources, that person is more likely to take out a lease on the waterbody as a whole..

### *3.4.3 Species preferences for stocking*

As mentioned, the selection of species for stocking depended on more than the performance of the fish in the system, i.e. the recovery and growth rates. Market price was an important factor but to investigate whether there were also additional criteria that were used to determine stocking matrices were constructed at each site to examine the fish stocked and their performance in freshwater and brackishwater systems according to a number of criteria selected by the respondents (Tables 10 and 11).

**Table 10 Performance of stocked fish species according to resource manager criteria in freshwater rice-fish systems in West Bengal.**

| Performance criteria | Location | Species stocked | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *C. catla* | *L. rohita* | *C.mrigala* | *O. niloticus* | *H. molitrix* | *P. javanicus* | *C. idella* | *L. bata* | *A. nobilis* | *C. carpio* | *M. rosenbergii* |
| Growth | Kamardanga | 5 | 4 | 5 | 5 | 5 | | | 5 | 5 | 5 | |
| | Janakichak | 4 | 3 | 2 | 3 | 5 | 3 | 5 | | | | 2 |
| | Mohantiki | 5 | 3 | 3 | | | 3 | 5 | | | | |
| Market price | Kamardanga | 4 | 4 | 4 | 5 | 2 | | | 5 | 2 | 3 | |
| | Janakichak | 4 | 4 | 3 | 4 | 2 | 4 | 4 | | | | 5 |
| | Mohantiki | 5 | 5 | 5 | | | 5 | 2 | | | | |
| | Pearypur | 4 | 4 | 2 | | | | | 4 | | 1 | |
| Recovery | Kamardanga | 3 | 3 | 3 | 4 | 4 | | | 4 | 4 | 4 | |
| | Mohantiki | 4 | 4 | 3 | | | 5 | 5 | | | | |
| Availability | Pearypur | 4 | 3 | 3 | | | | | 2 | | 4 | |

**Table 11 Performance of stocked fish species according to resource manager criteria in brackishwater rice-fish systems in West Bengal.**

| Performance criteria | Location | Species stocked | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *O. niloticus* | *Peneaus sp.* | *Liza sp.* | *C. catla* | *L. rohita* | *C. mrigala* | *Mystus sp.* | *L. calcarifer* |
| Growth | Jorria | 5 | 2 | 3 | 4 | 3 | 1 | | |
| | Tangramary | 4 | 4 | 2 | | | | 3 | 1 |
| Market price | Jorria | 5 | 5 | 4 | 3 | 3 | 1 | | |
| | Tangramary | 3 | 5 | 4 | | | | 4 | 4 |
| Availability | Tangramary | 3 | 1 | 3 | | | | 1 | 2 |
| Suitable for paddy | Jorria | 1 | 5 | 4 | 5 | 4 | 2 | | |

The results suggested that performance, and especially growth, and the market price of fish were indeed important criteria for selection but in addition factors such as seed availability and the suitability of the fish for growing alongside rice were also considerations. The results showed that trade-offs were made when selecting species and in species known to affect the rice such as tilapia with their nesting behaviour (in systems where fish culture was concurrent) were stocked because of high consumer demand and market price.

The rice-fish systems are dynamic and this means that the stocking density and combination of species could change over time. A good example of this is Janakichak where respondents indicated that the combination of species stocked had changed due both to changes in the waterbody that made it less suitable for shrimp culture together with increases in the market price of *L. calcarifer*.

### *3.4.4 Constraints faced by resource system managers.*

During the appraisal at each of the sites an attempt was made to elicit the main constraints faced by those managing the systems and what sort of information could benefit them. The constraints did not differ substantially between brackish and fresh water sites and so the results are aggregated over all sites (Table 12).

**Table 12 Summary of the constraints faced by managers of rice-fish systems in West Bengal.**

| Nature of constraint | Number of sites affected |
|---|---|
| Financial resources and access to credit. | 6 |
| Uncertainty regarding the ‘best’ combination of species and stocking densities | 5 |
| Seed availability (including additional constraint that large seed are more expensive) | 5 |
| Lack of technical advice e.g. on feeding | 5 |
| Disease (particularly of shrimp) | 3 |
| Seed quality | 2 |
| Low level of market access | 2 |
| Water controllability | 2 |

The main constraints across all the sites appear to be financial and technical in nature. It should be noted in this respect that the constraints listed are those faced by respondents under the current management systems. If the systems were to change, e.g. from collective leasing to collective management then it might be expected that a number of additional constraints such as difficulties in creating group unity and coordination for managing by themselves might also emerge. Finance has also been suggested as a major factor constraining the development of shrimp farming and inland aquaculture in a number of other studies (e.g. FAO 2001, Kumeran *et al*. 1993 and Suresh and Selvaraj 1991).

Technical issues – particularly uncertainty over which species to stock and stocking densities were also felt to be important constraints and FAO (2001), WorldFish (2002) and Bardan Roy *et al*. (2001) have all also noted that these technical issues constraints to management. One site, Pearypur indicated that their only constraint was financial and they had no need for further technical advice. Other sites were less intensive and much more limited in their access to resources and they raised a number of technical constraints. It should be possible to address some of these constraints and reduce some of the uncertainty through management experiments. Seed availability was also reported to be a constraint. This is interesting as Milwain *et al*. (2002) have believe that West Bengal has one of the best established and developed seed networks in Asia. This suggests that the constraint is more in the affordability of fish seed and/or access to the seed network.

Less important issues amongst the sites were seed quality and market access. Access to quality fish seed has also been suggested as a serious issue in fish culture in West Bengal by Milwain *et al*. (2002). As for marketing, FAO (2001) also identified low producer bargaining power in India as a major constraint to achieving maximum benefits from aquaculture. Water controllability was a constraint in two cases (Bedemary and Kamardanga) but this may well be a result of the sites selected to be visited as all had access to and were able to control water apart from these. The controllability issue differed, in Bedemary water was accessed via a canal that was managed and controlled by the irrigation department while in Kamardanga, the waterbody in question was subject to occasional flooding. Interestingly, while it was acknowledged that poaching and poisoning occurred and were fairly widespread activities, it was not mentioned as a constraint at any of the sites visited.

# 4 Discussion

Despite the severe limitations placed on the study concerning the timing, time available and staff availability it is felt that it was still possible to collect sufficient data to allow some insights into the fisheries conducted as part of rice-fish culture systems in West Bengal. Rice-fish systems, as a number of studies including this one have noted, are important sources of income to those managing the systems and of aquatic products for the wider population. However, it is also accepted that the outcomes of management interventions are not always predictable and benefits from the management of these systems could potentially be increased if some of the uncertainties associated with both the technical and institutional aspects of the system could be reduced. As a first step towards doing this, this appraisal has sought to provide some insight into the existing management of rice-fish systems and of the outcomes of this management. Framing this enquiry into by using the IAD framework has allowed a systematic investigation that encompasses both the technical, biophysical aspects of the resource system as well as the institutional, socio-economic aspects that also affect outcomes.

The nature of the resource systems varied quite considerably within the study area. Part of the reason for this is that the sites were selected to provide a wide range of system types. The systems could initially be divided into brackishwater and freshwater culture systems. Freshwater systems were mainly stocked with hatchery produced fingerlings (typically 7-10 cm) of Indian major carps with some stocking of species such as *P. javanicus* and Chinese carps. In addition some *M. rosenbergii* seed would be stocked. Brackishwater systems on the other hand were characterised by the stocking of smaller fry, caught from the wild or entering through sluice gates, of *Liza* sp. and *L. calcarifer*. The primary cultured species in these systems was *P. monodon* and in addition, some hatchery produced seed were stocked, typically *O. niloticus* and Indian major carps.

The main objective of management in all the systems was to generate income and the waterbodies were stocked as polycultures in order to maximise income and ensure that risk was spread in case of disease outbreaks. Stocking of these waterbodies had some scientific basis but was based more on the experience of the managers together with the availability of both shrimp and fish seed and financial resources. Three main categories of management were identified, namely private management by an individual or group of individuals, collective management and rental. On the basis of the information gathered it appeared that while renting was the most common form of management, respondents felt that the maximum benefits could be accrued through private or collective management. The cases of private management where the management entity was a co-operative as in the cases of Pearypur and Mohantiki relied on access to financial resources and

By combining the data from the appraisal with that from a number of other studies it was possible to investigate the main factors affecting yield in both freshwater and brackishwater systems. For brackishwater systems, as seed size did not vary much, it appeared that yields had a strong positive correlation with stocking density. For freshwater systems yields were similarly correlated with stocking density but also, and to a greater extent, to the size of seed stocked. Insufficient data was available to examine the effect of alternative species combinations but a bioeconomic model was developed to examine the trade-off between stocking larger fingerlings or increasing the stocking density of smaller fish. Initial results seem to indicate that increasing the size of fingerling stocked will provide better returns than increasing stocking density, perhaps due to the higher mortalities experienced by smaller fish.

The information collected was also used to build upon and extend previous work, such as that of Bardan Roy *et al*. 2001, in identifying factors that affected land use and the management of rice fish systems. It was possible to identify three key factors, namely salinity, water controllability and access to resources that could determine the options for land management and for the management of any rice-fish systems fishery. It is felt that this could benefit from additional studies to determine more fully the relevant importance of such factors and their implications fro land use and fisheries management.

Data collected and the results of the analysis indicated that performance of the species stocked was not the only criteria in selecting the mix for stocking. Other criteria, most notably the market price were also considered to be important. Resource managers also provided information about the constraints that they felt they faced. One of the most common amongst these was a lack of knowledge about technical aspects of fish culture such as stocking and feeding.

These uncertainties in management could possibly be reduced through an active management experiment that involves creating variation in management actions across a number of waterbodies in order to provide information. Potential experiments based on the results of the appraisal might include stocking different species mixes or varying stocking densities and evaluating performance of the different treatments against resource manager criteria. This would require calculating likely outcomes on the basis of likely recovery rates, growth, species interactions and market prices. An alternative, and related, experiment might be to quantify the extent to which fingerling size and stocking density affect yields in order to provide advice given the trade-off identified.

In addition to active experimentation it should also be possible to collect information relating to existing variation in management practices (passive experimentation) that will provide some additional insights into the systems that will be of use to those involved in managing the systems or those promoting them. Possible candidates for such an approach identified through the appraisal include the factors affecting land use and fisheries management and the factors affecting the success of cooperative and collaborative management arrangements.

In deciding on an active experiment, it will be vital that the principles of experimental design, including statistical power, are applied in order to assess whether proposed experiments are viable. This means assessing in the first place whether proposed treatments are likely to create enough variation to provide sufficient contrast in the response variable that a causal link can be established. As well as the variation between treatments, a related factor that also needs to be considered is the variation within treatments and effectively how many samples might be required. These are non-trivial issues as, in the first place, contrast in treatments can have important implications for the equitability of the treatments and one site may be getting what might appear to be a ‘better deal’. It is certainly the case that no treatment should be applied that will knowingly dis-benefit those involved. Ensuring adequate replicates can also be a major challenge, especially in systems that are quite variable. However, it is a crucial aspect and, though it may constrain what can be achieved, must be considered.

The information from this appraisal provides an indication of some of the uncertainties associated with the management of the rice-fish systems. This information will be shared and discussed with the resource managers and other key stakeholders and subsequently used to design an experiment. The experiment will generate information relevant to the needs and objectives of local stakeholders that will reduce some of the uncertainties and lead to improved management outcomes. These stages of the adaptive learning process are outlined in pages 20 to 23 of Garaway and Arthur (2002).

## References

Arthur, R.I. (2004) Adaptive learning and the management of small waterbody fisheries: a case study in Lao PDR. PhD. Thesis, Centre for Environmental Technology, T.H.Huxley School for the Environment, Earth Sciences and Engineering. London, Imperial College of Science, Technology & Medicine

Bardan Roy, S.K., N.K. Saha, P. Gascon and M. Hossain (2001). Adoption of rice-rice and rice-aquaculture farming systems in coastal West Bengal, India: determinants and impact. IRRI Report

Bhaumik, U., A. Mitra, S.K. Saha and T. Paria (2002). Professional health hazards among the fin and shell fish collectors of Sundarbans. Environment and Ecology **20** (3): 514-519.

Bhoumik, U., S.K. Saha and P.M. Mitra (1993). Scenario of brackishwater finfish and shellfish seed collection in the Sunderbans, West Bengal. Journal of the Inland Fisheries Society of India **25** (1): 44-50.

Bosch, O.J.H., W.J. Allen, J.M. Williams and A.H. Ensor 1996. An integrated system for maximising community knowledge: integrating community-based monitoring into the adaptive management process in the New Zealand High Country. The Rangeland Journal **18** (1): 23-32

Chattopadhyay, G.N., A. Ghosh and P.K. Chakraborti (1982). Possibilities of brackish water paddy-cum-fish farming in coastal saline soils of West Bengal. Paper presented at the 47$^{th}$ Annual Convention of the Indian Society of Soil Science, Nagpur.

Chattopadhyay, G.N., A. Ghosh and P.K. Saha (1983). A note on the possibility of salinisation of soils under paddy-cum-brackishwater aquaculture in some coastal saline soils. Journal of the Indian Society of Coastal Agricultural Research **1**(1): 43-45

Cowan, V., M. Aeron-Thomas and A.I. Payne. (1997). An evaluation of floodplain stock enhancement. London, MRAG Ltd.

Das, D.N., S.K. Bardhan Roy and S. Biswas (1993). Fish growth and natural fish food sources in deep-water and boro rice cropping system in Eastern India. Indian Agriculture **37** (1): 15-20.

De, D.E. and M. Sinha (1997). Seasonal abundance of the seed of commercially important prawns and fishes in the Hooghly-Matlah estuary during post-Farakkah barrage period. Indian Journal of Fisheries 44 (2): 201-209.

Demaine, H. and M. Halwart (2001). An overview of rice-based small-scale aquaculture. In: IIRR, IDRC, FAO, NACA and ICLARM Utilising different aquatic resources for livelihoods in Asia: a resource book. International

Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organisation of the United Nations, Network of Aquaculture Centers in Asia-Pacific and International Center for Living Aquatic Resources Management. 416p

De Silva, S. S. and U. S. Amarasinghe, Eds. (1996). Reservoir fisheries in Asia. Perspectives in Asian Fisheries, A Volume to Commemorate the 10th Anniversary of the Asian Fisheries Society. Manila, Asian Fisheries Society.

Dovers, S. and C. Mobbs 1997. An alluring prospect? Ecology, and the requirements of adaptive management. In: Klomp & Lunt. (eds). Frontiers in ecology. Elsevier.

Economist (2004). West Bengal: The thin red line. Economist, May 8 - 14, 2004: 28

FAO (2001). Production, accessibility, marketing and consumption patterns of freshwater aquaculture products in Asia: a cross-country comparison. FAO Fisheries Circular No. 973, Food and Agriculture Organisation of the United Nations, Rome.

Ganapathy, R. (1989). Present status of semi-intensive prawn farming technology in India with special reference to small holdings. In: Proceedings of a national workshop on brackishwater prawn farming for higher production. 23-25 October 1989, Bangalore: 106-114

Garaway, C. (1995). Communal Ponds in NE Thailand under different use-rights systems: a participatory rural appraisal of their differing roles in peoples' livelihoods. Centre for Environmental Technology. London, Imperial College, University of London.

Garaway, C. (1999). Small waterbody fisheries and the potential for community-led enhancement:Case studies in Lao PDR. Centre for Environmental Technology, T.H.Huxley School for the Environment, Earth Sciences and Engineering. London, Imperial College of Science, Technology & Medicine**:** 453.

Garaway, C.J., R.I. Arthur and K. Lorenzen (2002). Adaptive learning approaches to fisheries enhancement: final technical report. MRAG Ltd, London

Ghosh, A., G.N. Chattopadhyay and P.K. Chakraborti (1985). Rice-cum-fish cultivation in coastal paddy fields: package of practices for increasing production. Aquaculture Extension Manual New Series No. 6 December 1985, Central Inland Fisheries Research Institute, West Bengal, India. 16p

Grandstaff, S. and T. Grandstaff (1985). Semi-structured interviewing by multisiciplinary teams in RRA. International Conference on RRA, Khon Khaen, Thailand.

Grover, J. (2001). Aquaculture development and information processes. In: IIRR, IDRC, FAO, NACA and ICLARM Utilising different aquatic resources for livelihoods in Asia: a resource book. International Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organisation of the United Nations, Network of Aquaculture Centers in Asia-Pacific and International Center for Living Aquatic Resources Management. 416p

Hartmann, W. (1995). Institutional Development for common-pool resources management: a task in technical cooperation. The case of Kerala Reservoir Fisheries. V. Fisch. Eschborn, GTZ**:** 227-258.

Hassan, N. (2001). The importance of fish in household nutrition. In: IIRR, IDRC, FAO, NACA and ICLARM Utilising different aquatic resources for livelihoods in Asia: a resource book. International Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organisation of the United Nations, Network of Aquaculture Centers in Asia-Pacific and International Center for Living Aquatic Resources Management. 416p

IIRR (2000) Rice-fish culture in deepwater rice farming system. Report

Kangmin, L. (2001). Rice-based aquaculture in China. In: IIRR, IDRC, FAO, NACA and ICLARM Utilising different aquatic resources for livelihoods in Asia: a resource book. International Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organisation of the United Nations, Network of Aquaculture Centers in Asia-Pacific and International Center for Living Aquatic Resources Management. 416p

Kumar, R.S. (2002) Soil macro-invertebrates in a prawn culture field of a tropical estuary. Indian Journal of Fisheries **49**(4): 451-455

Kumaran, M., P. Ravichandran, B.P. Gupta and A. Nagavel (2003). Shrimp farming practices and its socio-economic consequences in East Godavari District, Andhra Pradesh, India - a case study. Aquaculture Asia **8**(3): 48-52.

Lal, B. (1990). Impact of Farakka Barrage on the hydrological changes and productivity potential of Hooghly estuary. Journal of the Inland Fisheries Society of India **22** (1&2): 38-42

Little, D.C., Kundu, N., Mukherjee, M. and Barman, B.K. (2002). Marketing of fish in peri-urban Kolkata. Institute of Aquaculture, University of Stirling Working Paper No6, December 2002.

Lorenzen, K., J. Juntana, J. Bundit, and D. Tourongruang (1998a). Assessing culture fisheries practices in small waterbodies: a study of village fisheries in north-east Thailand. Aquaculture Research **29**: 211-224.

Lorenzen, K. and C. J. Garaway (1998b). How predictable is the outcome of stocking? Inland fishery enhancements. T. Petr. Rome, FAO Fisheries Technical Paper 374**:** 133-152.

Lorenzen, K., C. J. Garaway, B. Chamsingh and T.J. Warren (1998). Effects of access restrictions and stocking on small water body fisheries in Laos. Journal of Fish Biology **53**(Supplement A): 345-357.

Mandal, S.K. and M.L. Bhoumik (1984). Prawn seed collection and developing seed trade in Sunderbans. Journal of the Inland Fisheries Society of India **16 (1&2)**: 51-52.

McAllister, M.K. and Peterman, R.M. (1992). Experimental design in the management of fisheries: a review. North American Journal of Fisheries Management 12: 1-8

Milstein, A. (1992) Ecological aspects of fish species interactions in polyculture ponds. Hydrobiologia 231: 177-186

Milwain, G.K., Little, D.C., Kundu, N. and Immink, A.J. (2002). Overview of fish seed production and distribution in West Bengal, India. Institute of Aquaculture, University of Stirling and Institute of Wetland Management and Ecological Design, Kolkata. Working Paper 7, December 2002.

Mohanty, R.K., H.N. Verma and P.S. Brahmanand (2004). Performance evaluation of rice-fish integration system in rainfed medium land ecosystem. Aquaculture 230: 125-135

MRAG, CIFRI and Department of Agriculture, West Bengal (2004) Identifying stakeholders and developing a means to enhance learning: A summary of the implementation of adaptive learning methodologies in West Bengal, India. Project Process report. MRAG Ltd.

Natarajan, A.V. and A. Ghosh (1982). Scope and relevance of paddy-cum-fish culture. Indian Farmers' Digest **15**(1): 32-40

Nguyen, S.H., Bui, A.T., Le, L.T., Nguyen, T.T.T. and De Silva, S.S. 2001 The culture-based fisheries in small, farmer-managed reservoirs in two Provinces of northern Vietnam: an evaluation based on three production cycles. Aquaculture Research **32**: 975-990

Oakerson, R. J. (1992). Analyzing the commons: a framework. Making the commons work: theory, practice and policy. D. W. Bromley. San Francisco, ICS Press.

Peterman, R.M. and M.K. McAllister (1993) A brief overview of the experimental approach to reducing uncertainty in fisheries management – an extended abstract. Canadian Special Publication in Fisheries and Aquatic Science 120

Pomeroy, R.S., B.M. Katon and I. Harkes 2001. Conditions affecting the success of fisheries co-management: lessons from Asia. Marine Policy 25: 197-208.

Quiros, R. and Mari, A. 1999 Factors contributing to the outcome of stocking programmes in Cuban reservoirs. Fisheries Management and Ecology **5**: 241-254

Reshad Alam, A.K.M., M.C. Nandeesha and D. Saha (2001). Community rice-fish farming in Bangladesh. In: IIRR, IDRC, FAO, NACA and ICLARM Utilising different aquatic resources for livelihoods in Asia: a resource book. International Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organisation of the United Nations, Network of Aquaculture Centers in Asia-Pacific and International Center for Living Aquatic Resources Management. 416p

Samina, Z. and E. Worby (1993) Nagashini beel: a case study of the transformation of a common property resource. NAGA The ICLARM Quarterly, April-June 1993, p7-8

Scoones, I. (1999). New ecology and the social sciences: what prospects for a fruitful engagement? Annual Reviews in Anthropology 28: 479-507.

Sinhababu, D.P., B.C. Ghosh, M.M. Panda and B.B. Reddy (1984). Some preliminary observations on physico-chemical characteristics of soil and water under rice-cum-fish culture. Journal of the Inland Fisheries Society of India **16**(1&2): 58-61

Suresh, R. and P. Selvaraj (1991). Adoption behaviour of fish farmers in relation to credit availability in freshwater aquaculture - a case study. p. 220-221 In: Proceedings of the National Symposium on new horizons in freshwater aquaculture (23-25 January, 1991) CIFA.

WorldFish (2002). Increasing and sustaining the productivity of fish and rice in flood-prone ecosystems in South and Southeast Asia. Final Report to IFAD prepared by WorldFish Center, Penang, Malaysia

## Appendix 1  Survey form to collate existing knowledge about waterbodies and their management.

Information for initial site selection   Region: ______________________ Completed by: ______________________

| Site number | District | Site or farmer | Waterbody | | Flooding (month) | | Management (C/I/L) | Stocking (Y/N) | Rainy season use | Boro rice (Y/N) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Area (decimal) | Depth (m) | Arrives | Recedes | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

# Appendix 2 Length-weight conversions.

In the course of the analysis it was sometimes necessary to convert estimates of fish length to weight. In order to do this the following equations, based on the associated length weight curves, were used where lengths are in centimetres and weights in grams. It may be noted that the fit for M. rosenbergii is less good and this may be a result of the growth pattern of crustaceans where the carapace is shed at intervals resulting in growth in stages.

***Labeo rohita***:

$$LnWeight = 2.383 LnLength - 2.528$$

$R^2 = 0.911$;   n = 34

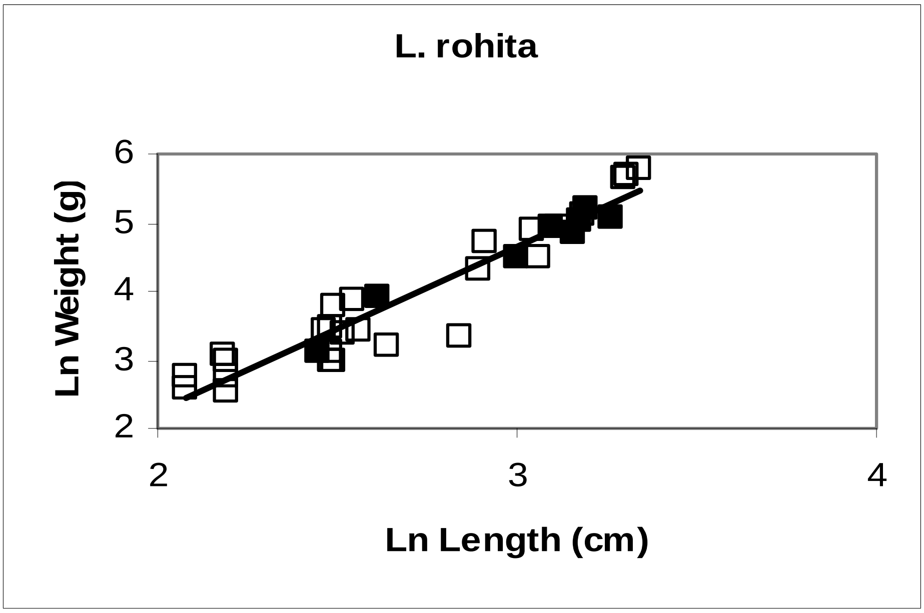



**Figure 12 Length weight conversion curve for *L. rohita* either with supplemental feeding (■) or without (□).**

***Cirrhinus mrigala***

$$LnWeight = 2.337 LnLength - 2.290$$
$R^2 = 0.923$;   n = 11

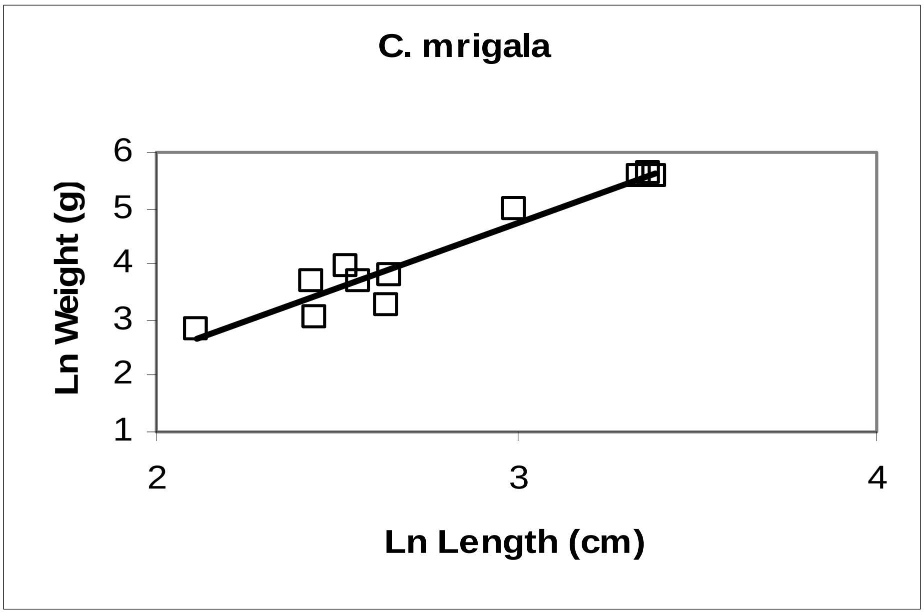



**Figure 13 Length weight conversion curve for *C. mrigala*.**

***Cyprinus carpio***

$$LnWeight = 2.534 LnLength - 2.519$$
$R^2 = 0.932$;   n = 34

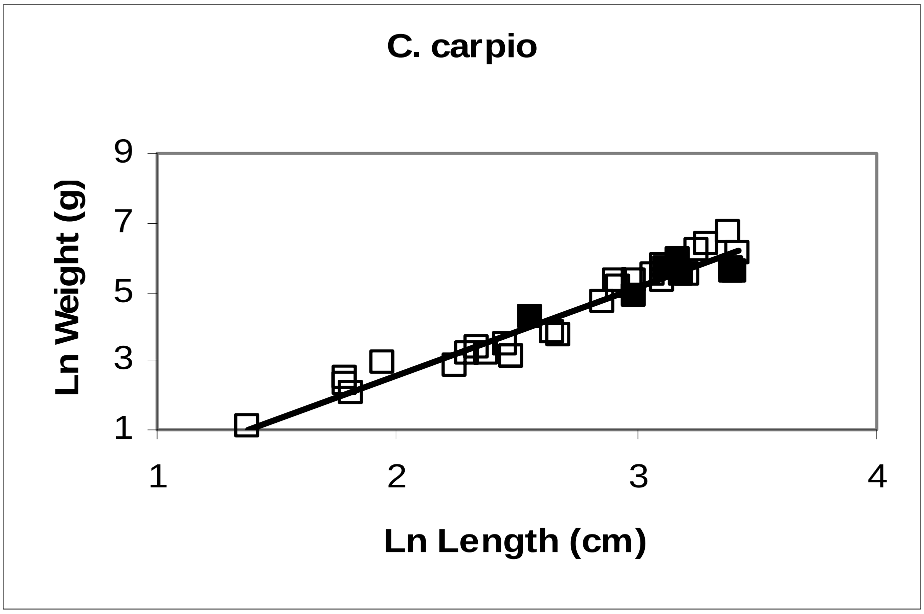



**Figure 14 Length weight conversion curve for *C. carpio* either with supplemental feeding (■) or without (□).**

***Macrobrachium rosenbergii***

$LnWeight = 2.122 LnLength - 1.863$
$R^2 = 0.923$;    n = 11

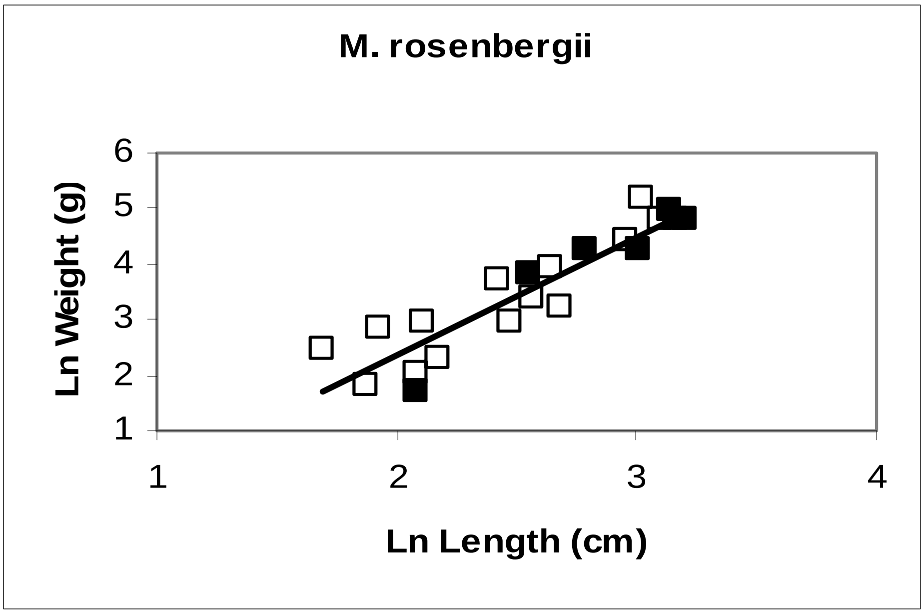



**Figure 15 Length weight conversion curve for *M. rosenbergii* either with supplemental feeding (■) or without (□).**

***Puntius javanicus***

$LnWeight = 2.351 LnLength - 2.212$
$R^2 = 0.923$;    n = 11

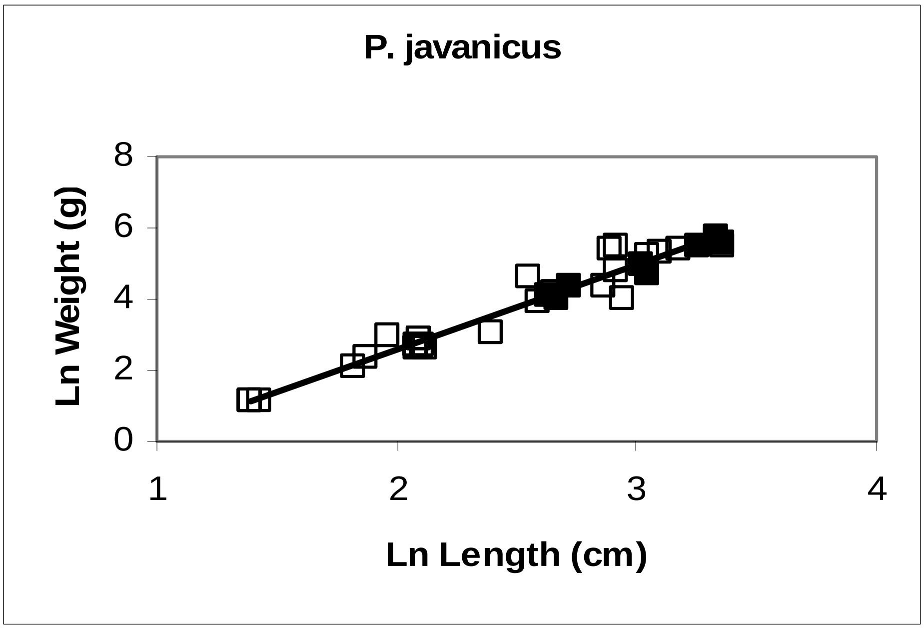



**Figure 16 Length weight conversion curve for *P. javanicus* either with supplemental feeding (■) or without (□).**