Integration of Aquaculture within Irrigation Systems: a poverty-focused approach

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Abstract

The potential for aquaculture to be integrated within a large-scale irrigation system taking a poverty-focused approach was investigated in the Mahaweli System H irrigation system of North Western Province, Sri Lanka. Using a livelihoods approach an initial situation appraisal identified the potential for aquaculture to be integrated within existing livelihoods activities. The appraisal revealed that decreasing returns from farming and fishing seasonality were major sources of household vulnerability. Using fish caught from the tank fishery, small-scale cage-based fattening of tilapia was developed with participants in an attempt to mitigate seasonal vulnerability caused by fishing seasonality.

Participatory technology development was conducted with members of two communities within Mahaweli System H. Upon identifying resources and formulating a research agenda with participants, pilot trials were conducted by fisher-farmers in USG village and by a group of female cage operators in RAJ village.

The study identified several constraints to sustainability of the culture system such as variable and low availability of small tilapia with which to stock cages, poor feed quality and latterly, competition for feed inputs. Despite their initial enthusiasm, women were particularly disadvantaged in this process as they were unable to catch their own fish with which to stock their cages and became dependent on men to assist them.

The study showed that the cage-based fattening system was able to help meet emergency household expenses, although it was not efficient enough nor practiced on a large enough scale to contribute greatly to household security. In this manner, holding and fattening smaller tilapia is comparable with livestock holdings.

Further development of cage design and feed administration improvements are needed to reduce production costs and improve the economic viability of the system.

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Chapter 1 Introduction

1.1 Background

Challenges faced by more and more countries in their struggle for economic and social development are increasingly related to water (GWP, 2000). Decreasing availability of freshwater resources is set to become even more important as the demand for water increases due to the world's rising population and increasing demand for food. When 70% of the world's supplies of developed water i.e. that which is used for productive purposes such as agriculture or industry, is used by irrigation and overall withdrawals[1] are forecast to increase, growing scarcity and competition for water add a new dimension to the food security debate (Seckler *et al.* 1998)

In Asia, the most populous continent, the relationship between water resources and poverty is marked. A realisation that multiple use of scarce water resources is essential to stabilise or improve livelihoods is growing (World Resources Institute 1996, FAO 1995, UN 1994, Gleick 1993). The global population has increased by a factor of three in the last century and water withdrawals have increased by a factor of seven (GWP, 2004). In the late 1990's the number of countries facing a water deficit has grown to twenty- six. Managing water efficiently whilst maximising its food production potential is critical to meet the demands of increasing populations in water stressed countries. It is estimated that almost half the world's poorest people, nearly

[1] Extraction of water for consumptive use which may or may not return to the system.

500 million, live in drought prone areas and depend on irrigated agriculture for their food security, and that proportion is set to rise further by 2050 (Engleman and LeRoy, 1993). If this trend is not reversed, two thirds of the world's population will face water shortages in one form or another by 2050 (Abu-Zied 1998; Gleick 1993). Increases in irrigated areas for food production are failing to keep up with the increasing population (Postel 1993). By early next century developing countries as a group can be expected to become net importers of food. For the poorest of these countries - most of which are found in sub-Saharan Africa and South Asia - the financing of food imports will be a high priority, and capture fisheries and aquaculture will come under strong pressure to provide exportable products (FAO, 1998). Therefore, the issue of efficiently utilising freshwater resources to feed the world's growing population is an area in timely need of investigation, in particular within irrigated areas.

It has been predicted that India and Sri Lanka will face a freshwater crisis in the near future (Nigam *et al.* 1998) therefore these countries were selected as the target research sites for the DFID – funded KAR Project R7123, "Integration of Aquaculture within Large-Scale Irrigation Systems". This thesis is an output of the project. A particular objective of project R7123 was to identify how and where the poor living in irrigated areas of India and Sri Lanka could benefit from aquaculture integrated within their local irrigation schemes. A particular focus therefore, was defining the characteristics of their poverty and to what extent aquaculture in irrigation systems could contribute to poverty alleviation in either context.

1.2 Poverty: definitions, concepts and measurement

Poverty, its nature, definition and measurement, has been the subject of much discussion within the literature. Several terms have been used to describe poverty; income or consumption poverty, human development, social exclusion, ill-being, lack of capability and functioning, vulnerability, livelihood unsustainability, lack of basic needs and relative deprivation (Maxwell, 1999). Absolute poverty refers to the subsistence below minimum, socially acceptable living conditions, usually established based on nutritional requirements and other essential goods. Relative poverty compares the lowest segments of a population with upper segments, usually measured in income quintiles or deciles (Lok-Dessallien, 2000). The manner in which poverty is measured reflects fundamental assumptions as to its nature and causes (Lok-Dessallien, 2000).

There is a growing realisation that poverty can no longer be viewed in terms of monetary variables alone and merits broader attention to other non-economic factors to address the mechanisms which cause, or could potentially lead to, poverty alleviation. Sen (2000) in his seminal work, Development as Freedom, makes the assertion that poverty cannot be viewed in income terms alone and should be viewed in terms of an individual's capabilities to attain the freedoms which can enable them to escape poverty. This approach acknowledges the complexity of poverty and that a reductionist approach will have limited impact on addressing the root causes of poverty and deprivation worldwide.

Poverty levels can vary considerably within regions of the same country, which means that aggregated variables favoured in such elements as GNP per capita or Human Development Index, favoured by large development institutions as they can be compared internationally, can fail to disclose the highly variable spatial nature of poverty within a given context. Poverty can also be temporal in nature and the transient nature of poverty can mean that snap-shot analyses do not account for the movement of people (individuals, families and communities) in and out of poverty (Maxwell, 1999).

More recently, sustainable livelihoods concepts have developed to encompass this multi-faceted nature of poverty (DFID, 1998). This thesis draws on the sustainable livelihoods approach to provide a holistic understanding of poverty. The nature of this approach is explained further on in this chapter.

1.3 Irrigation systems: an overview

Irrigation systems can be classified as either small-scale or large-scale systems. Small-scale irrigation systems usually comprise of a single or network of small water bodies (SWBs) and canals, which deliver water to irrigate local cropping areas. In many cases management is decentralised and is normally achieved through small user groups. Large-scale irrigation systems, however, are comprised of larger reservoirs or ‘tanks’ that feed a network of irrigation canals. These systems tend to be planned and organised at a regional level and irrigate several thousand hectares of cropping land. They are usually managed centrally by institutions such as an Irrigation Authority or Public Works Department which are external to the community. In general terms, they are managed by engineers, hence sometimes referred to as engineer-managed systems. A schematic representation of an irrigation system showing its sub-systems is presented in Fig 1.1. Any need for water storage arises due to the unequal temporal and spatial distribution of water. Therefore construction of storage reservoirs and dams has been necessary to store a proportion of seasonal rainfall and floodwater to regulate discharge and supply water to irrigate land downstream during the dry season (Haylor, 1994).

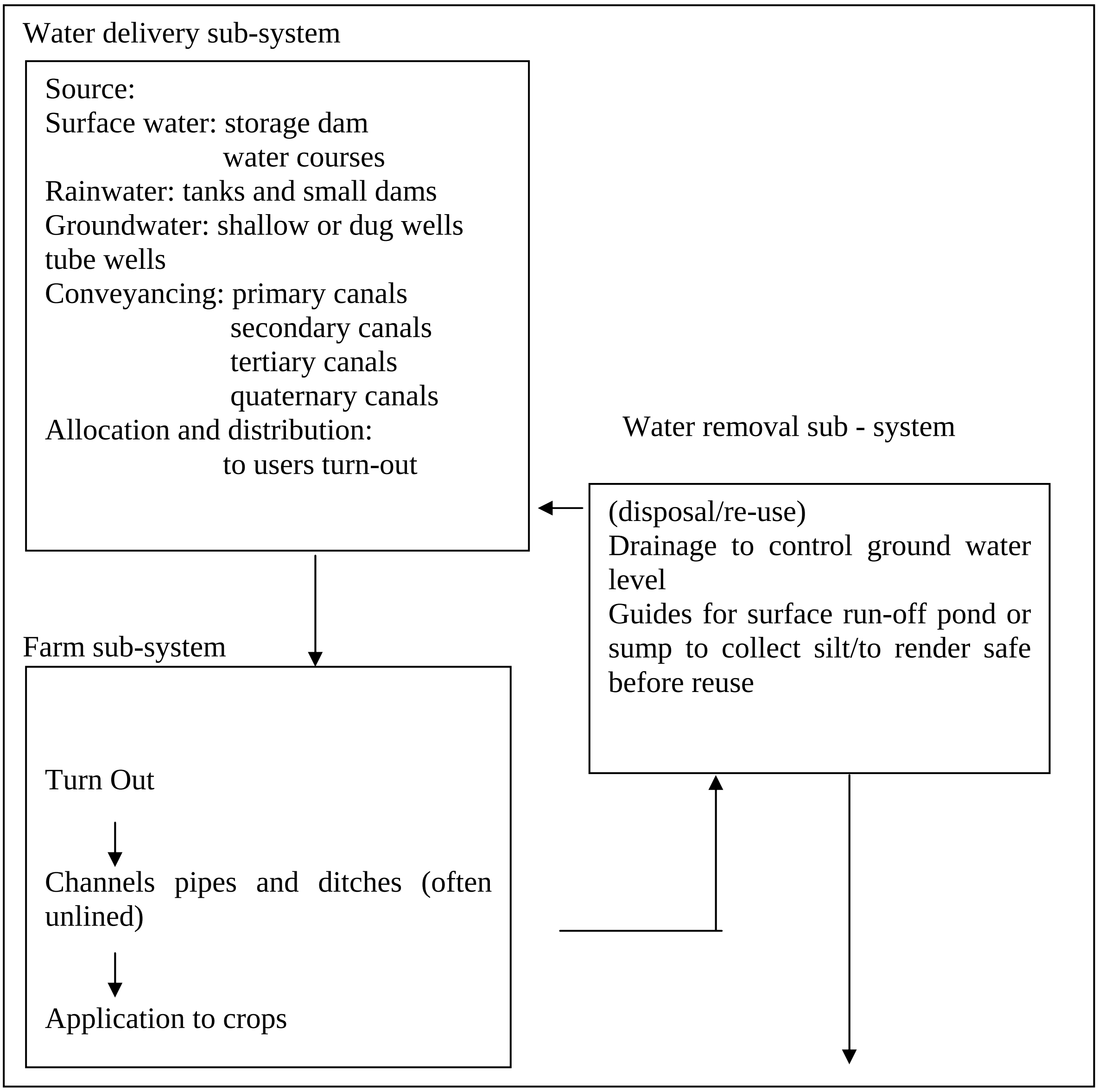

Figure 1.1 Principal components of a generalised irrigation system

Source: (Haylor, 1994)

In many developing countries improving the performance of canal irrigation systems has taken precedence over other management alternatives. Dealing with large seepage losses from canals (usually addressed through canal lining projects), poor mechanisms for distributing water to farmers and lack of control of the timing and quantity of water releases are just some of the issues that require attention if efficiencies are to improve. Generation of revenue for irrigation and appropriate water pricing for users has received much attention of late. However, the strong link in many developing countries between agriculture, GDP and food security has led some governments to delay action on this issue for fear of detrimental effects on agricultural economics. In some developing countries, government revenues from irrigation average only 10-20% of the cost of delivery (Postel, 1993). The low revenue generated from charging for irrigation and consequent low re-investment in irrigation maintenance and development, perpetuates the problem of optimising water use. In Pakistan (Rinaudo, 2002) and in South India (Wade 1982; 1985; 1990 and Mollinga 1998), corruption is blamed for poor water allocation within irrigation systems and consequently successful ground-level implementation of improved irrigation policy remains a considerable challenge. Therefore advances in water management face socio-economic and institutional constraints in addition to engineering issues.

Food security has been addressed to some extent through agricultural intensification and consequent production increases achieved through the Green Revolution technologies. From the 1960’s onwards the demand for water for irrigation has grown due to the introduction of water-intensive crops developed during the Green Revolution (Rinaudo, 2002). This period saw the development of high yielding crops and the consequent expansion and development of irrigation infrastructure. Modern, high yielding rice varieties have been quickly adopted since the 1970s in several Asian countries. In South Asia, which has 63% of the worlds' irrigated land, yields of rice and wheat have almost doubled in the last 30 years (IRRI, 2001). Increasing production led to increased employment for the landless around large-scale irrigation systems due to quicker maturation times of crops and increased demand for labour. Food security, at least in rice and other grains, was achieved in many countries as production increased and the price of grains (such as rice) decreased. Overall this decrease in price had a positive impact on poverty (Pingali *et al.* 1998). Despite this, benefits of the Green Revolution for producers were not uniform. Larger farmers benefited the most from improved technologies as they could afford to buy into the technology required. With the economies of scale possible on larger farms this increasingly marginalized small producers. In India agrarian change of this kind has increased the gap between rich landowners and the rural poor (Beck, 1995).

To ensure food and nutrition security it is essential not only to increase the total food production, but also to ensure availability for the poor (Kent, 1997). Given that water has now become a significant limiting constraint to irrigated agriculture, on which most South Asians depend, the issue of food security is now firmly back on the development agenda. There is now a growing need for more efficient and multiple use of irrigation systems for food production to meet the future demands of the world's population. While much attention in the food security debate has been focused on rice, little has been made of the contribution of other important dietary food sources, such as fish, to address protein and micro-nutrient malnutrition. Asians consume the largest quantity of fish per capita with the mean consumption being 14 kg/capita/year outside of China. Fish accounts for at least 40% of animal protein the diet and is an important source of micronutrients such as fat-soluble vitamins, minerals and essential fatty acids (Sugiyama *et al*. 2004).

1.4 Fisheries, Culture-Based Fisheries and Aquaculture

Following the success of the Green Revolution in increasing agricultural production, many national and international development agencies turned their interest to realising the potential to increase food production from the aquatic environment (Bailey, 1985), although on a somewhat smaller scale. This shift to exploitation and improved productivity of the aquatic environment has been termed the Blue Revolution (Martinez, 1998). Increasing production from the aquatic environment has occurred in two ways; firstly by promotion and adoption of advanced fisheries technology or provision of subsidies for fishing craft to increase exploitation of fisheries and, secondly to intensify aquaculture production of species in high demand or with a high market value. FAO (2004) define aquaculture as “The farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated”. Edwards (1999) makes the distinction between land-based and water-based aquaculture systems. Examples of land-based aquaculture systems include indoor recirculation tank-based systems or pond aquaculture. Land based systems require water to be withdrawn from a water source and used for fish culture before being discharged back into the body of water from which it was withdrawn, usually resulting in degradation of water quality with implications for other resource-users. Water-based aquaculture systems are those such as cage and pen aquaculture situated in existing water bodies such as lakes, reservoirs, rivers, canals and the coastal zone. These are non-consumptive systems in that water does not need to be withdrawn from an external source in order to facilitate production. However, these systems are characterised by their lack of control over the quality of the external environment and can in turn affect the quality of water for other users. Culture-based fisheries can also be broadly categorised as a water-based aquaculture system as they cannot be sustained without the involvement of aquaculture to produce fry or fingerlings for re-stocking (De Silva, 2003).

Capture fisheries are defined as the exploitation of natural stocks in water resources which may or may not be regulated by a user group or institutions. Capture fisheries both marine and inland, produced an estimated 132 million tonnes of fish in 2003 (FAO, 2004). Outside China, the world's population has been increasing more quickly than the total food fish supply (FAO, 2004). This means that future increases in demand for fish will have to be met by aquaculture (Tidwell & Allan, 2001), hence the need for research to contribute towards 'fish security' as part of the quest for sustainable food production systems.

Culture-based fisheries are defined by FAO (2004) as activities aimed at supplementing or sustaining the recruitment of one or more aquatic species and raising the total production or the population of selected elements of a fishery beyond a level which is sustainable through natural processes. In some cases stocking to enhance production takes place where there is already a self-sustaining population of smaller indigenous[1] but less valuable fish species and stocking is viewed as a way to increase production of higher value species with greater market demand. Culture-based fisheries have played an important role in fisheries reservoir fisheries development where reservoirs have been created through impoundment. This has been particularly useful in maintaining or enhancing fish production where valuable lacustrine species have been unable to establish self-recruiting populations due to their inability to breed in lentic water bodies (De Silva, 2003). Ownership of fishing rights of culture-based fisheries may be held by an individual or a group and access is normally controlled. This can create conflicts where the access rights to water bodies have changed once the value of the resource has been reclassified as a commercial fishery and may endanger the livelihoods of small, artisanal, fishers who are also dependent on extraction from the water body. This is commonly achieved by introducing hatchery-reared fingerlings into community water resources such as seasonal tanks or ponds.

1.4.1 Fish production in Asia

Asian aquaculture makes a large contribution to world fish production; 85% of the people employed in aquaculture and fisheries live in Asia (FAO, 2002). The number of people involved in fish farming has doubled in Asia from 3,980,000 to 7,132,000 in 2000 in the 10 years between 1990 and 2000 most of which has occurred in China, the worlds largest aquaculture producer (FAO, 2002). Since 1970, aquaculture has increased at an average compounded rate of 9.7% per annum compared with 1.4% for

[1] In some instances indigenous fish are more valuable (D.Little, pers .comm.). However, market value and appeal may be related to the size of fish or other characteristics.

capture fisheries and 2.8% for terrestrial meat production. By far the most common aquaculture system used in Asia is pond aquaculture. Pond aquaculture is normally practiced on an extensive to semi-intensive scale in Asia (Halwart *et al*. 2000). Over 80% of fin-fish production in Asia is from fertilised ponds with carp and tilapia being the most popular of the farmed species. This is largely because of the ability of fish culture in ponds to be integrated with other agricultural practices, where water is stored in an on-farm pond (Edwards *et al*. 2000).

Aquaculture development has met with criticism because it has often resulted in increased production and benefits for the few, often to the environmental, social and economic detriment of others (Lewis, 1997). The development of aquaculture using ponds means that pond or land access or ownership is a pre-requisite to participation. Many of Asia's poor are landless and miss out on these development opportunities as they have neither access to, or ownership of, a fish pond nor the land on which to construct one. Recognising that the poor are often excluded from the direct benefits of production-oriented aquaculture development initiatives has taken a long time. There is now growing emphasis on aquaculture *for* development rather than aquaculture development (Friend and Funge-Smith, 2002).

The potential for the poor to gain direct benefits may play a role in both food security and poverty alleviation, however, little is currently known about the role of aquaculture within irrigation systems specifically, with particular emphasis on how the poor benefit from such systems.

1.5 Fisheries and aquaculture in poverty alleviation

Aquaculture and aquatic resource management and recognition of its capacity to alleviate poverty has evolved over the past 20 years. In many countries aquaculture development has been conducted with a top-down, technology driven agenda to increase production. The increasing recognition that aquaculture can contribute to food security and poverty alleviation has partly stemmed from the research and development community's increased understanding of the factors that contribute to poverty as a whole. There has been a shift from top-down, transfer of technology approaches to a far more participatory bottom-up approach to development. In Africa, conventional approaches to aquaculture development were proven to have little impact on the poor (Harrison *et al*. 1994). Until recently, few projects had specifically targeted the poor and a great deal of national level aquaculture development strategy focused on increasing production, failing to recognise the potential role of aquaculture in food security. Identifying and creating opportunities for the poor to engage in aquaculture will be critical if aquaculture *for* development is to become a valid strategy for national or international poverty alleviation.

Different aquaculture systems can contribute to poverty alleviation, however, this can depend greatly on the type of resources to which the poor have access. Edwards (2000) identified some key direct and indirect means in which aquaculture can contribute to poverty alleviation. Producers experience directly improved availability of high quality protein and increased income. Other indirect benefits include increased availability of fish in the rural market place, which may decrease the price of fish and favour the poor, increased productivity from common pool resources (such as that experienced through integrated cage aquaculture) and employment opportunities in auxiliary roles.

However, for the poor to participate in aquaculture this activity must fit within their livelihood activities and recognise the security of their access to, or ownership of resources. In addition, appropriate training and financial support must be in place to facilitate sustainable participation of the poor in aquaculture (Kent, 1997).

In order for aquaculture to develop with a pro-poor approach, several key components are pre-requisites; a reliable supply of, and access to, water; adequate seed of appropriate quality and quantity at the right times; appropriate feeds or fertilisers for pond systems; good market demand and reliable micro-credit systems. When these parameters are in place aquaculture has been shown to be successful in areas where it was not traditional practice (Van der Mheen, 1999).

Two types of aquaculture which do not require access to, or ownership of land are cage and pen aquaculture systems. Cages are units of varying sizes which can be fixed or floating and installed in a variety of water bodies. They must hold fish securely whilst ensuring that water movement is sufficient to maintain good water quality for fish held within. Complete feed is often required as access to natural food may be restricted. Pens are larger enclosures which are created by fencing off an area of a water body using piles driven into the bottom substrate and mesh panels. As the structure is fixed harvesting can only be achieved as water levels decrease, therefore a fairly predictable rise and fall in water levels is required to facilitate harvesting. Pen culture can be extensive but is largely a semi-intensive system where supplementary feed is provided. Fish in pens may access natural food and their movement is largely unrestricted.

Cage culture has been identified as an approach that allows major changes in the productivity of common pool resources without the conflicts associated with intensification of fisheries management (Beveridge, 1987). In recent years the role of small-scale aquaculture production specifically addressing the needs of the poor in Asia has been initiated. McAndrew *et al.* (2002) and Munzir and Heidhues (2002) demonstrate the way in which cage aquaculture practised on a small-scale can benefit the landless poor in rural Bangladesh and Western Sumatra respectively. The CARE CAGES[1] project in Bangladesh sought to increase the participation of the poor in aquaculture by developing small-scale cage culture systems specifically targeting the poor. This enabled marginalized landless groups to undertake cage aquaculture in communal access water bodies. The initiative was supported through a network of local NGOs providing micro-credit. However, the long-term sustainability of cage aquaculture in Bangladesh remains to be established and rests on the assumption that the current enabling environment for small-scale cage operators remains and that the enterprise does not fall into the hands of the elites once its potential for income generation is further realised.

[1] Cooperative for Assistance and Relief Everywhere (CARE) Cages for Greater Economic Security (CAGES) project.

1.6 Irrigation systems; multi-purpose use and potential for integration of aquaculture.

Agriculture in South Asia uses over 80% of the available water supply (Wilson, 2004). However, growth of agricultural production has slowed to a dangerous level and threatens world food security (Abu-Zeid, 1998). In irrigated areas water is used for many purposes other than irrigation of field crops, such as watering home gardens, trees, washing clothes, bathing and livestock watering (Bakker, *et al.* 1999) as well as well as supporting activities such as fishing and harvesting of aquatic animals and vegetables. These other uses of water have long been ignored as agriculture has received the main recognition from policy makers, planners and water managers.

Aquatic production is one example of how water can be utilised for food production. Prevailing water shortages in South Asia make the potential for integrating fish production into irrigation schemes an important researchable issue (Haylor and Bhutta, 1997). Irrigation policymakers and planners often fail to recognise the contribution that fish and other aquatic products provide to system users and solely focus on irrigation management for crop production. There is growing evidence that fish production from irrigation systems plays an important role in both income generation and household food security for the poorest groups (Halwart, 2003). Improving fish production in irrigation systems is an area in need of consideration as one possible approach to reducing poverty in irrigated areas of developing countries. In short, the increasing population, increasing pressure on freshwater resources, shortfalls in global fish production and a slowdown in agricultural production makes the case for improved food production from those water resources. Therefore, integrating aquaculture into irrigation systems as a non-consumptive water use could contribute to improved food security for the poor in many water-stressed developing countries.

1.7 Large-scale irrigation systems; components and potential for aquaculture

The main components of the irrigation system can be classified as storage structures and delivery systems. Storage structures are often the result of impoundment of rivers but can also be naturally occurring lakes and reservoirs. Reservoirs collect rainfall during the monsoon periods but are also important collectors of runoff from the surrounding land of the catchment area. Consequently water levels may vary according to season. In some engineer-managed systems releasing water downstream through a series of sluices and canals can control water levels. Where this system is operated seasonal fluctuations may be less marked.

In the farming sub-system of these large irrigation schemes storage structures also exist in the form of on-farm reservoirs (OFRs), ponds and paddy fields. Expansion of on-farm reservoirs (OFRs) has also expanded in areas in which drought otherwise constrained any intensification of cropping (Little & Edwards, 2003).

The delivery component of the irrigation system refers to the networks of canals and field channels originating from storage structures. Canals form conveyance networks which may be lined or unlined and shaped to create the optimum velocity for water delivery and prevention of siltation (Haylor, 1994).

There is a growing recognition of the potential for “integrated aquaculture within irrigation systems” mainly due to the potential complementarities of integrating aquaculture within storage of the system as a whole or within the farming sub-system (ALCOM, 1998; Haque, 1996; Fernando and Halwart, 2000). Examples of reservoir-based cage and pen aquaculture are described by Costa-Pierce and Soemarwoto (1990). The latter demonstrated the positive impact of cage aquaculture on the livelihoods of resettled, landless communities in Saguling Reservoir in West Java, Indonesia. Cage aquaculture activities were however, eventually overtaken by elites once the economic value was realised. In some cases, such activities are not accessible to the poor as producers as capital costs involved in cage or pen culture operations exceed their economic means.

The establishment of enclosure, pen or cage culture in a water body can alter or limit its value as a multipurpose resource (Haylor, 1994). Cage and pen structures can have impacts such as altering current flows and sedimentation patterns. Cages may even attract criticism for being unsightly. Beveridge (1984) reported that in Laguna de Bay in the Philippines the unchecked expansion of pen culture caused obstruction to boat traffic, which in turn led to conflict between the operators and other resource users whose access to homes and fisheries was impeded by the cages.

Cage culture presents an opportunity for people to participate in aquaculture irrespective of land holding. Cages are even equipped as homes in the Lo River, Vietnam (Little *et al*. 2000). In instances where the poor are landless, a feature of many parts of Asia, cage aquaculture offers some potential for a poverty-focused approach to aquaculture.

1.8 Fisheries in Irrigation Systems

In addition to the potential for aquaculture to be integrated within irrigation systems, steps have been taken to augment fish production from both large reservoirs and small seasonal water bodies.

Bighead carp in reservoirs in Singapore (Yang, 1982) and silver carp in reservoirs in Israel (Leventer and Teltsch, 1990) have been used to control algal blooms maintaining water quality for other resource users. Many Indian reservoirs are largely used as culture –based fisheries for carp production, although a substantial amount of production is accounted for by non-stocked species such as tilapia, estimated to account for 24% of the catch in inland waters of Tamil Nadu (Sugunan, 1995). However, statistical reporting of the contribution of stocked varieties and non-stocked varieties in the catches of Tamil Nadu state operated culture-based fisheries are unreliable (*pers. obs*.) and modified to fulfil carp production targets.

Developing culture - based fisheries in large reservoirs through fisheries enhancement has been discredited in Sri Lanka due to poor recapture rates of stocked fish and the inability of riverine carps to establish self-recruiting populations (Amarasinghe, 1998). In Sri Lanka this has resulted in a shift in fisheries development strategy to focus on the promotion of carp stocking in small seasonal water bodies (many of which are used for irrigation storage). In these systems natural productivity is high and their small size facilitates harvesting hence recapture rates are thought to be higher. This potentially presents a better return on stocking than the larger reservoirs where recapture is more difficult due to their larger area and depth. Culture-based fisheries integrated within small-scale irrigation systems have been reported by De Silva *et al.* (2000) and Murray (2004) in Sri Lanka, with the latter taking an explicit poverty focused approach by stocking fish with greatest relevance to the poor communities around these seasonal tanks. Stocking in small seasonal water bodies in African countries such as Burkina Faso, Mali, Ghana and Zambia and Zimbabwe has also been promoted by large regional development initiatives to increase production (ALCOM, 1996). Garaway *et al*. (2000) and Lorenzen & Garaway (1998) also report the exploitation of culture-based fisheries in small seasonal water bodies in Laos PDR.

1.8.1 Integration of aquaculture within the farming sub-system.

Rice-fish aquaculture

Aquaculture within the farming sub-system can also be integrated with rice production (Halwart, 1998); Fernando, 1993; Dela Cruz et al., 1992 ; Coche, 1967). Rice-fish production is largely practiced in China, where 3.6% of the total rice producing area in the country is integrated with fish culture in this manner (Halwart and Gupta, 2004). Egypt is the next most important country in terms of the area under rice fish production, although the practice has also been reported in Bangladesh, India, Philippines, Thailand and Java, Indonesia (Halwart, 1998). Concurrent rice - fish culture, where fish are raised at the same time as rice, is the most common practice in India (under rain-fed conditions) and in Egypt (under large-scale irrigation) (Frei &

Becker, 2005). Fish are grown with rice as the crops are irrigated with water. This actually increases the economic viability of paddy culture by providing a double crop and reducing the pesticide input with positive environmental and financial benefits (Halwart and Gupta, 2004). The main constraints experienced are due to the impact of modern rice varieties as they require less flooding and have shorter growing periods. The areas where rice-fish aquaculture has worked the best, such as China and Java, Indonesia, are often linked to the local demand for large fingerlings for stocking in farm ponds (Halwart, 1998).

On-farm reservoirs (OFRs)

Water storage structures within the farming sub-system, such as on-farm reservoirs (OFRs), ponds and paddy fields, can also be considered suitable for some forms of aquaculture (Haylor, 1994). Prein *et al.* (2002) notes that in the upland areas of Quirino Province, Philippines, farmers collected runoff water from irrigated paddy fields to supply fish ponds fertilised by household and agricultural by-products as part of an integrated recycling system.

However, lack of land ownership for rice-fish culture in paddy fields or pond culture can constrain the capacity of aquaculture to have a significant impact on the poor if they are landless (Friend & Funge-Smith, 2002). In some cases it is access to, rather than ownership of, resources that is a more important factor (Kelkar *et al*. 2000). Access can permit the poor to exploit productive opportunities providing that there is no conflict with other users. The use of small, 1 cubic metre cages in Bangladesh to exploit village ponds is one example where access to a common pool resource has permitted aquaculture to be practiced by the poorest groups (McAndrew *et al*. 2000).

1.8.2 The Delivery Sub-System.

Redding & Midlen (1991) and Haylor (1994) reviewed the potential for aquaculture in engineer-managed irrigation systems with the former reviewing opportunities specific to canals. As canals form the main components of the delivery sub-system the following highlights areas where aquaculture in canals has been practiced.

Aquaculture in canals

It is often assumed that an assured supply of water is required for fish culture to be viable but in practice aquaculture has often been adopted in rain-fed areas in Asia where water supply is seasonal and less assured (Little *et al*. 1996). There is a strong seasonal component to water availability within canal networks in large-scale irrigation systems as water supply tends to coincide with cropping seasons. Irrigation canals in engineer-managed systems are principally operated to meet crop water requirements and irrigation is not usually concerned with supporting fisheries, aquaculture or other water uses (IWMI / GWP, 2005). Therefore, the challenges that the integration of aquaculture within canal networks face are both technical and institutional.

Non-consumptive aquaculture in running water delivery structures of irrigation systems is particularly appropriate for water-stressed regions of South Asia. The technical feasibility requires further research although anecdotal evidence of fish culture in the delivery system is cited (Redding & Midlen, 1991). Edwards (1986) reports that Thai carp have been cultured in canals although high mortality rates (40%) were experienced. Common carp have been cultured in drainage and sewerage canals in Bandung, West Java, Indonesia (Vaas and Saachlan 1956, cited in Redding and Midlen 1991). Costa-Pierce and Effendi (1988) found that large cages installed in Indonesian sewage canals served a dual purpose allowing silt to be harvested during the monsoon period. Cages in canals have also been reported in Egypt by Sadek (1988), Ishak (1986) and Jauncey and Stewart (1987). Despite water quantity and quality variation, water velocity should be taken into consideration (Beveridge (1987) recommends that velocity should not exceed 1 metre per second.

Pen culture is more commonly practiced in lakes, however, there are instances where pen culture has been integrated into irrigation canals. Tapiador and Coche (1977) report pen culture in the canals of the Yangste river delta in China, although no production data is presented. In Shaoxing province, pens have been installed in canals to fence of sections and act as a small fishery for Chinese carps.

Although these systems appear to work technically, they are less appropriate for the poor due to the high level of capital investment required for construction of large cages or pens. In some systems, pelleted feed may be required which, in turn, may increase operating costs.

Having discussed the areas in which aquaculture is currently integrated within irrigation systems, there is a lack of research to demonstrate where these systems have been able to meet the needs of the poor. In many of the systems identified land is a pre-requisite or, for water-based systems, high capital costs are required for cage fabrication. Low cost systems, which explicitly target the poor around irrigation systems, are adopted as the focus of this thesis as they are the most pressing area in need of research. The research approaches used throughout this thesis are reviewed below.

1.9 Research approaches

1.9.1 The Livelihoods Approach

Sustainable Livelihoods (SL) approaches have been developed from other development frameworks (Ashley & Carney, 1999) with the aim of improving understanding of the complexity of livelihoods, whilst assisting in identifying suitable entry points for external support that are compatible with, and appropriate to, vulnerable people's livelihoods strategies and priorities (Farrington *et al.* 1999). It is now widely acknowledged that poverty is complex and that macro-economic indicators, whilst indicative, do not reveal or help to address the root causes of poverty. The SL approach attempts to account for a variety of these causal factors which create impoverishment by reviewing the individual, household or communities' assets, both in terms of their access to, and ownership of, resources and the way in which micro and macro level policies, institutions and processes affect mobilisation of their capabilities.

Sustainable livelihoods approaches also seek to examine ways in which household vulnerability can be managed but largely focus on the availability of assets at the household/community level and look at the factors that affect the accumulation of, or access to, these assets. Five asset categories are conceptualised by the framework.

- Human capital - human capacity to earn a livelihood such as their health, education and age

- Social capital – the degree to which social connections and status can be used to contribute to livelihoods
- Natural capital – access to land, water or forested areas, which can be exploited in order to earn a living
- Physical capital – ownership of tools, means of transport, and other assets which could be used to derive an income
- Financial capital – Assets used as a means of saving such as cash, jewellery or even livestock. Access to credit can also be included in this category.

The Sustainable Livelihoods approach has widely been adopted by international development agencies as a means of identifying developmental needs and strengthening capacity at the household, community and institutional levels. Reardon and Vosti (1995), Sen (1997), Moser (1998) and Bebbington (1999) have provided different frameworks for analysing and describing livelihoods. International agencies such as DFID, CARE, Oxfam, and United Nations Development Programme (UNDP) developed their own livelihoods frameworks to assess poverty for intervention and monitoring activities. When reviewed these approaches were found to contain similarities in their foci. All agencies adopted an asset-based approach to classifying poverty status and some addressed capabilities as well as assets and activities. All stressed the need to facilitate effective micro-macro links between the poor and policy makers (Carney *et al.* 1999), so that effective linkages between micro-level interventions and policy could be made.

The DFID SL framework seeks to quantify livelihoods according to degrees of vulnerability, the quantity and nature of assets and the interaction of these aspects with policies, institutions and processes to establish livelihoods outcomes and strategies employed by households in communities. The framework is presented in Fig. 1.2. Understanding these factors provides a broad overview of the nature of poverty in a given context. Hence the DFID SL framework was used in this thesis as the most recent comprehensive framework for assessing the contributing factors to poverty at the household and community level.

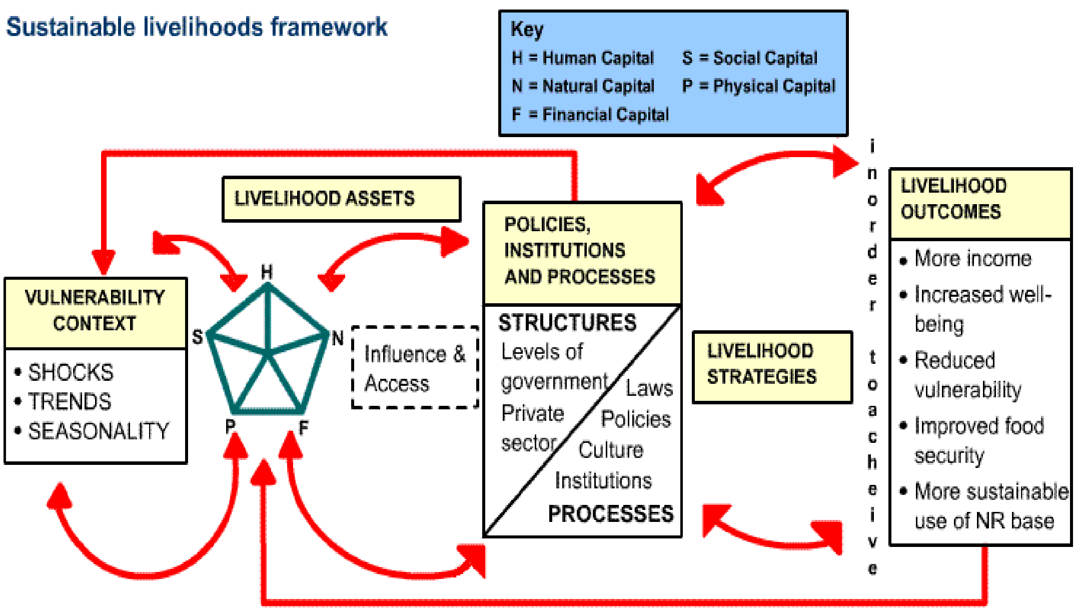

Figure 1.2 The DFID Sustainable Livelihoods Framework *Source* (DFID, 1998)

Several underlying principles of the Sustainable Livelihoods approach are outlined in DFID (1998). The approach is 'people centred', assuming that sustainable delivery of poverty alleviation will only be successful if it is what people want and is complementary to their current livelihoods strategies. The SL approach should be 'dynamic' to recognise and respond to changes in livelihood strategies. Approaches to poverty alleviation should also be ‘participatory’ promoting involvement of the poor rather than persisting with top-down approaches. Tackling poverty should also be ‘multi-level’, ensuring that micro-level activity informs policy and that there are appropriate structures and processes at macro-level to support people and strengthen their capacity. Sustainability is also promoted, finding an important balance between the four components of sustainability, namely economic, institutional, social and environmental. Partnerships between the public and private sector are also emphasised by the approach.

Focusing on vulnerability as a key component of the framework recognises that there are interactions between assets and the factors that influence them. Vulnerable households may not necessarily be poor, but the quantity and nature of household assets plays an important role in determining household resilience to negative events such as shock and trends, which may impact on the household livelihood outcome.

Since its development, the DFID Sustainable Livelihoods framework has been used as a monitoring and evaluation framework around which changes in household assets, access and activities can be initially assessed against a baseline. Baseline information collected through using a livelihoods approach can also be used to identify suitable entry points for development or research interventions. It should be noted that the sustainable livelihoods framework is not a method but rather a framework to guide methodologies in recognising all the components that exist and interact in livelihoods of households, communities and regions.

1.9.2 Approaches to pro-poor aquaculture research

Research approaches to identifying opportunities for poverty-focused aquaculture in irrigation systems will require a multi-disciplinary approach (Gowing *et al*. 1999). The approach should be participatory, people-centred and combine socio-economics with technical objectives.

The use of participatory approaches to identifying researchable issues and for adaptive research has been widely promoted (Pretty *et al*. 1995) but their role in areas with little current aquaculture practice, knowledge or infrastructure has yet to be established.

1.9.3 Systems Approaches

In systems analysis, the analyst attempts to compartmentalise and sub-divide the world in which we live into small and describable units or systems, viewed as a series of 'wholes' (Checkland, 1981). Largely linear and reductionist by nature, systems analysis has wide-ranging applications in hard sciences, industry and management, but increasingly in social and behavioural sciences. "Hard" systems thinking is the kind of approach principally applied to describe and solve technological problems and processes. A problem is defined and through a series of structured events and processes a solution to the problem is found. Hard systems processes are often viewed independently of any interaction with social or political interference. Ludwig von Bertalanffy (Von Bertalanffy, 1981) furthered this view and classified systems in terms of being 'open' or 'closed' in relationship to their exchange with the environment. Organisms, organisations and people, although in an organised hierarchy of structures, engaged in import and export of material between the 'open' system and its environment. More recently systems thinking has developed to acknowledge that whilst "hard" systems analysis and behaviour have a role to play, the interactions of social, political and behavioural elements have a critical role in determining success. Recognising these contributory factors has been at the core of the emergence of "soft" systems methodology. Checkland and Scholes (1990) developed soft systems methodology, which explicitly recognises the importance of non-technical influences on systems analysis. The soft systems approach is characterised by its focus on identifying a 'problem situation'. This is based on the recognition that there are multiple contributory factors to a given problem, whether social or technical in nature. The soft systems approach investigates the complexity of real-world problems and recognises that real-world 'problem situations', such as those of poverty or development, are not linear and are in fact multi-faceted with many interacting factors, many of which are affected by the external environment within which they operate. This has led to the integration of so-called human adaptive systems (Emery & Trist, 1981) into the agenda for many scientists. Previously, taking hard systems approaches to tackle development problems has failed to provide sustainable outcomes - the top-down, transfer of technology approach being one such example. A soft systems approach, of building up a rich picture of information with stakeholders before development intervention, has superseded transfer of technology in many development organisations and institutions. This more holistic approach yields large amounts of information, but it is informative and vital to ensure constraints are identified before resources are allocated on socially or economically unviable programmes.

1.9.4 Systems thinking and its applications for poverty-focused aquaculture research

Understanding where aquaculture fits within the context that it is introduced to is crucial. Aquaculture can be viewed as an open system as inputs are imported from the outside environment and outputs exported to markets and consumers. Edwards (1998) states that in order to properly understanding how certain integrated aquaculture systems work, one must have an understanding of fields such as agriculture, ecology, economics, engineering, environmental science and sociology.

Edwards (1998) describes a model for a sustainable aquaculture system and highlights that the three components: production technology, socio-economics and environmental, must be fulfilled. The production technology component encompasses such aspects as species selection, the required culture facility and husbandry, indicating that the cultured species influences the choice of culture facility and required husbandry method. However, culture facility and available husbandry knowledge and labour may also exert an influence on the choice of species.

The socio-economic component of the system can comprise both macro and micro level issues. At the macro level this can be the effect of current government development policy, market conditions, availability of subsidies and cultural attitudes to fish production and aquaculture products. Micro-level issues may be reflected at the household or community level and normally deal with competing use of resources for aquaculture or alternative income generating activities. Where there are complementarities for integrated aquaculture production there remains the opportunity for conflicts to arise over use of resources for agriculture, aquaculture or other activities. Aquaculture is not always viewed as the best use of resources for social or economic reasons and this must be understood in order to assess the likely sustainability of aquaculture as an income generating activity.

The environmental component deals with the environment external to the culture system. Many environmental concerns relate to the degradation of water quality caused by aquaculture, caused in particular by the discharge of wastes and overuse of chemotherapeutants. However, grave socio-economic consequences - including conversion, expropriation and privatization of mangroves and other lands; salinization of water and soil; decline in food security; marginalization of coastal communities, unemployment and urban migration; and social conflicts - have followed in the wake of shrimp farm development in the Philippines and other tropical countries (Primavera and Honculada, 1997). There are, however, positive environmental impacts of aquaculture. Pond culture can provide eutrophic water for crop irrigation (Wood *et al*. 1999) reducing the demand for chemical fertilisers to be applied. In Vietnam, human waste (night soil) is used as an input for pond fertilisation and hence a positive solution to a human waste treatment problem is addressed by integration with an aquaculture production system, although systems of this type have the potential to cause human health problems such as bacterial, viral and trematode infection (Pescod, 1992).

In recent years there has been growing attention to the importance of social sustainability of development activities. Understanding the potential for, and impacts of, aquaculture on livelihoods will be essential to the success of any technical intervention.

When both the livelihoods and systems approaches are combined a clearer indication of where aquaculture may fit in a given context can be gained and areas of overlap and interdependency between livelihoods systems and aquaculture systems identified and used for mutual benefit.

1.9.5 Participation and participatory methods

The need for participatory situation appraisals and the "participation paradigm" evolved after years of top-down, production led, approaches to development. Many applications of participatory methodologies refer to agricultural development in developing countries however, similarities are shared with how aquaculture development has progressed. In the transfer-of-technology paradigm scientists made research decisions and technology was developed in research stations and then handed to extensionists to pass on to farmers. But this approach has missed local complexity and failed to account for the adaptive performances of farmers. Technologies successful in one context have been applied irrespective of context, with widespread failure (Pretty & Chambers, 1994). This realisation that outsiders[1] did not have all the answers to the needs of the poor led to a paradigm shift towards increasingly participatory, bottom-up, locally driven approaches. Participation has also been recognised to contribute to more effective and sustainable impacts (Cornwall *et al.* 1994). Development practitioners have begun to implement participatory approaches which aim to tackle poverty in a bottom-up manner, driven by needs and aspirations identified by people *in situ* rather than those prioritised by outside assistance.

[1] 'Outsiders' is a term that can be used to define both people visiting communities from developed countries and also those from developing countries with different cultural backgrounds and/or urban attitudes (Cornwall, *et al*,. 1994).

Increasingly practitioners seek to gain greater understanding of the complexity of local situations to better target development assistance. Incorporating local people's knowledge into the synthesis of appropriate poverty-focused strategies has become part of this process. Participation has become a prerequisite for development lending or project funding however, differing perceptions and interpretations of what exactly constitutes participation exist. Both Biggs (1989) and Pretty (1995) have graded participation into various levels. Biggs (1989) categorised participation into four levels in relation to work on farming systems research. Contract and consultative participation is classified at the lowest end of the participatory scale where participation is largely extractive and fairly passive. In these lower categories, 'participants' contribute to the research process through the provision of information and facilitate use of village resources by researchers. Collaborative and collegial, at the top end of the participation scale, encourage participation in the design and implementation phases of research or development projects, encouraging peoples' continuous input, interaction and evaluation to their completion. Participatory technology development (PTD) is one example of collaborative participation in action. Decision making at the collegiate end of the scale is either jointly between participants and outsiders or made by participants themselves. In a similar attempt to acknowledge that participation has many levels, Pretty *et al*. (1995) identified seven levels of participation. These represent a gradient from participation in a top-down, passive manner where people are essentially told what is going to happen to them to a collegial, self mobilising and rights-based approach to development where client groups are encouraged to make demands on institutions and organisations to fulfil their needs. In a research context the latter shares similarities with participatory action research where 'empowerment' and ownership of the process by the participants is a key feature. Both authors' classifications overlap considerably in their descriptions, but they both serve to highlight that participation has multiple levels and depends on the goal to be achieved and the context in which it is employed.

Participatory methods

Numerous 'participatory' appraisal methodologies have arisen, some aiming explicitly to collect information in order to identify research and development needs, others to monitor and evaluate their impact. Rapid rural appraisal (RRA) and participatory rural appraisal (PRA) are just two methodologies in popular use for evaluating situations in development planning, however, strict classification of the boundaries of these methodologies seem to have become blurred. A new title of PLA (participatory learning and action) has appeared in some resource books (Pretty *et al*. 1995; Alders *et al*. 1993) and increasingly PRA has become less rural and the same approach is used in urban settings (Ellis, 2000). Townsley (1996) listed the following generalised characteristics of both approaches whilst acknowledging the overlap between these broad classifications.

Table 1.1 Potential differences between RRA and PRA (Townsley, 1996)

POTENTIAL DIFFERENCES BETWEEN RRA AND PRA	
RRA	PRA
• Responding to needs of development workers and agencies	• Responding to needs of communities and target groups
• More emphasis on efficient use of time & achievement of objectives	• More emphasis on flexibility to adapt to time frame of community
• Communication and learning tools used to help outsiders analyse conditions and understand local people	• Communication and learning tools used to help local people analyse their own conditions and communicate with outsiders
• Focus of RRA decided by outsiders	• Focus of PRA decided by communities
• End product mainly used by development agencies and outsiders	• End product mainly used by community
• Enables development agencies and institutions to be more "participatory"	• Enables (empowers) communities to make demands on development agencies and institutions
• Can be used purely for "research" purposes without necessarily linking to subsequent action or intervention	• Closely linked to action or intervention and requiring immediate availability of support for decisions and conclusions reached by communities as a result of the PRA

Rapid rural appraisal (RRA) is just one approach where a number of qualitative tools and methods are used prior to development interventions. During the 1980s, RRA methods were used to involve people in the process of collecting and synthesising information about their lives and their communities. The need for a cost effective and multidisciplinary means of information collection coupled with the costs and constraints involved in more structured approaches to appraisal were the driving forces behind the evolution of RRA. However a key constraint of the RRA approach was the difficulty in finding and fielding a multidisciplinary team with the right mix of skills on an appropriate time-scale. Participatory rural appraisal (PRA) developed from the RRA concept during the 1990s to devolve greater control in decision-making and identification of needs to community members themselves. Robert Chambers has advanced much of the work on the use of PRA (Chambers, 1994a; Chambers 1994b;

Chambers 1994c) advocating that researchers and development specialists engage in a "new professionalism", beginning to shift away from structured, top-down approaches to development, instead focusing on the needs of those whom they intended to benefit. The PRA approach was used and the importance of rural peoples' knowledge (RPK), much of which has strong technical socio-cultural links, was acknowledged. One objective of PRA was to empower local people rather than 'outsiders' to identify their own development strategies. PRA methodology shares similarities with action research where research needs are identified by participants themselves with the hope of creating more sustainable outcomes for development.

While some practitioners may argue that the use of PRA methods is the ideal approach to promoting appropriate development, it is not necessarily complementary to the objectives of research projects and subsequent interventions. In the context of the present research project, adhering to a predetermined logical framework to investigate the opportunities for aquaculture within irrigation systems, an underlying assumption was that people would be interested in participation in aquaculture rather than a self-selected objective. Therefore, the following participatory situation appraisal was broadly RRA and consultative in nature, but adhered to some of the tenets of PRA such as researcher self awareness and worked in partnership with local institutions.

1.10 The study area

The number of people living in water scarce counties will rise from 132 million in 1990 to 653 – 904 million in 2025, rising by 2050 to 20% of the global population (Engleman and Leroy, 1993). The situation will be particularly severe in South Asia where food self-sufficiency targets may be impossible to achieve (Falkenmark, 1997). As India and Sri Lanka are predicted to face freshwater crises in the near future (Nigam *et al.* 1998), the multipurpose use of water resource will require increasing attention. The study area selected was Sri Lanka and in particular, the large-scale irrigation systems of the North Western Province.

1.11 Sri Lanka

The country of Sri Lanka is located in the Indian Ocean, 6-10° N, 80-82° E, covers an area of 65 610 km^2 and has a population of 19.4 million (World Bank, 2004). According to the World Bank (2004), 77% of Sri Lankans live in rural areas and it is in those areas that the percentage of people living below the poverty line reaches 38.1%. Although the mean annual income of Sri Lankan is $ 1010, higher than other nations in South Asia, there is concern that the development potential of Sri Lanka has not been reached. There are acute regional disparities in the levels of poverty (Kelegama, 2001), with the poorest families mainly found in the war-affected north and northeastern areas of the country. In many instances, transitory poverty caused by disruptions of the war (displacement) has declined into chronic poverty (Korf and Silva, 2003). However, there are also pockets of poverty found elsewhere in the country. The government's Samurdhi scheme aimed at supporting the poorest groups through provision of means tested benefit is corrupt and distributed between the upper 3 quintiles of the income scale, rendering the poorest groups without essential economic assistance (Brugere, 2002). The country is divided in to three distinct agro-ecological zones defined by the rainfall each receives. The respective zones and study area shown in Fig 1.3.

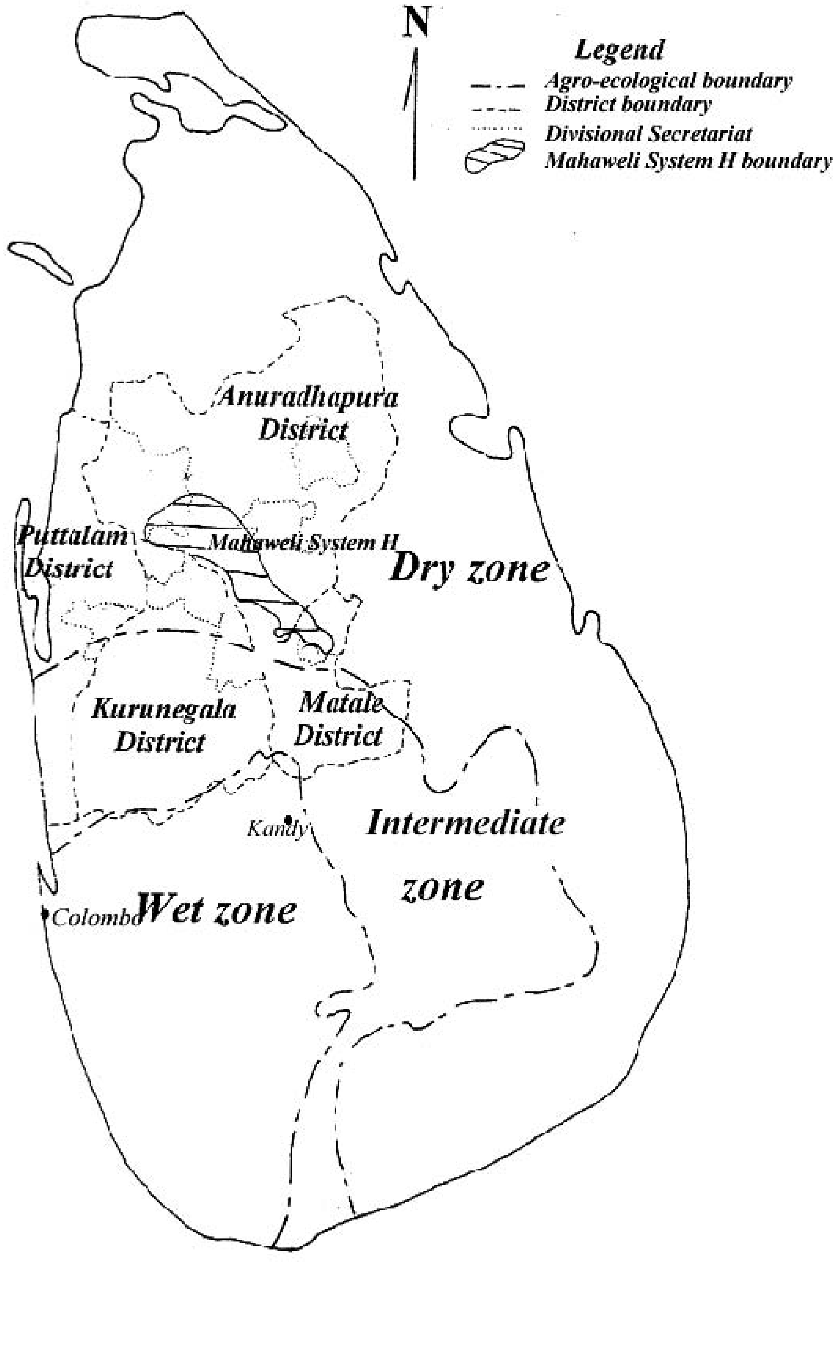

Figure 1.3 Map of Sri Lanka (Modified from Murray, 2004)

The lowland dry zone, where this project took place, covers an area representing 70% of Sri Lanka's land. The rainfall in the dry zone is between 651-1900 mm per annum falling in two monsoon seasons, which correspond to the South Asian Northwest and Southeast monsoons. These two seasons are known as *maha* (late September to February) which accounts for 60-70% of rainfall and *yala* (late February – June), which accounts for 20-40%. *Maha* is the major cultivation season.

Local institutional structure

Beyond these agro-ecological zones the country is divided into 9 Provinces and 25 districts. Within each district there is a layer of Divisional Secretariats which contain some 30-40 *Grama Niladhari* (GN) divisions. Each GN division comprises around 4-8 villages. The *Grama Niladhari* office has a resident *Samurdhi Niyamak*e officer who is responsible for overseeing the distribution of the government's Samurdhi benefit scheme, which provides a basic welfare payment to families on a means-tested basis. Records of all village births, deaths and marriages are also kept with the *Samurdhi Niyamake.* The *Samurdhi Niyamake* is often appointed from the local village and has detailed local knowledge of the socio-economic status of many of the villagers whom they serve.

Sri Lankan Agriculture

Approximately 80% of Sri Lankans live in rural areas. People living in these rural areas are highly dependent on agriculture with 41.5% of the employed women and 35.4% of employed men are engaged in agriculture and allied sectors (FAO, undated). The state is the dominant landlord in Sri Lanka and imposes restrictions on land sales and uses (Ross and Savada, 1988). Constraints to agricultural development such as irrigation subsidies and a trend towards off-farm employment in rural areas drive farmers into a repetitive cycle of paddy cultivation year on year, with less potential to farm higher-value crops for profit. The majority of irrigated cultivation is of paddy, which is the staple of the Sri Lankan diet. Cultivation of vegetable crops in home gardens and *chena*, a form of slash and burn agriculture in small cleared jungle plots, is also commonly practiced.

Macro-economic policies have negatively affected farmers over the years and eroded the returns from farming. In a drive to succeed in agricultural self-sufficiency, government policy prior to 1977 provided farmers with assured markets and stable prices for their produce (Weeragoda, 1998). This was coupled with extensive promotion of pesticides to farmers and other input subsidies. Post 1977 a change of government led to a shift in policy and abolishment of the protectionism from which Sri Lankan farmers had benefited. Trade liberalisation policies sought to encourage greater market orientation and increase efficiencies amongst producers (Kodithuwakku, 1997). Export orientated economic growth was another key objective. Farmers have failed to make a significant impact on the export market due to poor access to suitable market channels for their produce (Sinathamby and Noguchi, 1997; Narapalasingam, 1999). Globalisation and in particular, the influence of cheap agricultural produce from India, have exacerbated competition in the export market and cheap imports of Indian produce such as onion and chilli have contributed to farmers' woes. With little opportunity to export their produce many farmers feel compelled to cultivate traditional rice varieties which are less water efficient, retaining the majority for household consumption and selling any remaining seasonal surpluses in the local marketplace.

1.11.1 Inland water resources

Sri Lanka has no natural lakes and many of the tanks in Sri Lanka are formed from ancient irrigation reservoirs, some as many as 2000 years old. Little has changed to the planning and layout of the irrigation schemes (De Silva, 1988). Many of the ancient irrigation works have now been rehabilitated to serve their purpose for agriculture, although there are many minor irrigation schemes that remain undiscovered and are not apparent on the maps. Ancient reservoirs in Sri Lanka are generally shallow, between 5-10m in depth, not exceeding 15m at full supply level and have a small gradient (De Silva, 1988). The water availability in many of the tanks varies in response to demand for water for irrigation purposes and in response to rainfall. Some irrigation reservoirs also receive drainage water from other areas of the irrigation system.

1.11.2 Sri Lankan Fisheries and Aquaculture

Fisheries

The fisheries sector plays a vital role contributing as much as 65 – 70 % of the animal protein to the Sri Lankan diet and accounts for up to 81% of animal protein in rural areas of the country's dry zone (Nathaniel, 2000). The mean per capita fish consumption of Sri Lankans is 16.9 kg/year. Ariyapala (1956) has reported that inland fisheries have existed on an artisanal basis as far back as the 13th Century B.C. Around 90% of the country's consumption needs are caught from Sri Lankans marine and inland fisheries, the remaining 10% met by imports. The inland and capture fisheries have developed since 1970 with the assistance of hatchery-based inputs from international donors such as IDRC, JICA and FAO and production from the inland fishery increased as a direct result. However, the introduction of the exotic cichlid *O.*

mossambicus and increased exploitation of the fishery have been the main factors behind dramatically increasing fish yields in inland tanks. State patronage for inland fisheries development was withdrawn in 1990 due to pressure from the marine canneries industry to reduce competition and from senior Buddhist clergy, who deemed killing of fish to be in conflict with Buddhist religious beliefs. According to NFDP (1995) these factors caused production from inland fisheries to drop from 31, 000 metric tonnes in 1990 to 12,000 metric tonnes in 1994. However, it is more likely that the apparent drop was the result of a stoppage in data collection as inland fishing continued (Agalawatte, 1999). Post 1995, government support for inland fisheries was reinstated with a 5 – year development plan instigated by the Ministry of Fisheries and Aquatic Resource Development (MOFARD). This has led fisheries development down a route of seed production, stocking initiatives, subsidies for pond construction and loans for canoes (MOFARD, 1995) the impacts of which are discussed further in this chapter.

Since the introduction of *O. mossambicus* in 1952, and again in the 1970s of *O. niloticus*, tilapia have successfully colonised the reservoirs of Sri Lanka. As omnivores, tilapias are able to utilise a wide range of feeding niches within the reservoirs. Tilapia are also able to breed over a wide range of sizes which assists their resilience to increasing fishing pressures (De Silva, 1988). Size at maturity was reported to have decreased from 16cm to 13cm amongst *O. mossambicus* populations in Tissawewa (Pet, 1990) as fishing pressure increased. A declining size at landing has also been reported and attributed to growth overfishing[1] (Amarasinghe, 1988). The recommended mesh size of 8.9 cm (stretched mesh) is based on the premise that the use of meshes above this size will not cause levels of fish stock exploitation in perennial tanks to exceed maximum sustainable yield. It is postulated that stunting of tilapia has occurred as a result of fishing out larger and faster growing tilapia (with larger nets), imposing positive selection for smaller and slower growing fish (Pet *et al.* 1993). If the hypothesis is true, in some reservoirs adherence to the 8.9 cm mesh size may be worsening the situation rather than arresting any decline of the fisheries.

Although the unchecked exploitation of fisheries has the potential to lead to a "tragedy of the commons" scenario (Hardin, 1968) it seems that through their adaptive ecology tilapias have responded to increasing fishing pressure and maintained populations in most tanks. This resilience of the tilapia fishery to increasing pressure ensures that at least for the meantime, the inland fish supply on which the rural population depends continues to meet their consumption needs.

Fisheries management in the inland sector is largely top-down and there is no differentiation in the rules to account for differing tank types or fishery characteristics. Much fisheries research has centred on predictive yield modelling using differing methods of exploitation (De Silva, 2000; Fernando, 1999; Wijeyaratne, 1993; Pet, *et al*. 1993; Pet & Piet, 1993; Pet *et al,* 1993; Amarasinghe & De Silva, 1992; De Silva,

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[1] Growth overfishing is when the young fish that become available to the fishery (the "recruits") are caught before they can grow to a reasonable size (Pauly, 1983)

1988; Amarasinghe, 1983) aiming to identify means in which yields from reservoirs can be increased.

Whichever ecologically derived management strategies prove most effective in principle, implementation of fishery exploitation rules on the ground remains problematic. Within the tank fishing communities of Mahaweli System H, Watson (1999) found that fisheries management regulations were difficult to implement due to the under resourced extension service and the visible lack of enforcement. The possibility that non-compliance to fisheries regulations is driven by poverty in fishing communities requires further investigation. In the context of Mahaweli System H, poverty and lack of enforcement are likely to render fisheries management decisions aimed at controlling catches and gear use ineffective. Therefore, a greater understanding of the livelihoods context amongst stakeholders is required before proposed resource exploitation strategies based on fisheries modelling research can hope to be effective.

Aquaculture in Sri Lanka

Many government led initiatives have paid great attention to the development of aquatic production in Sri Lanka, however, there has been no large-scale adoption of aquaculture. Private sector development of shrimp aquaculture in the coastal sector (Siriwardena, 1997) and ornamental fish culture in the inland sector (Perera, 1998) are two exceptions indicating that there is both private sector capacity and entrepreneurship. Farming of the black tiger prawn, *Penaeus monodon*, was a successful and lucrative venture until major disease outbreaks occurred in the late 1980s (Wijepoonawardena and Siriwardena, 1996). Despite this, the contribution of both of these systems to poverty alleviation is limited as they are only likely to employ the poor as labourers (the shrimp industry at one point supporting up to 40,000 farm workers) and do not benefit the poor through the local marketplace as farmed shrimp is prohibitively expensive and shrimp and ornamentals are exported.

Three types of aquaculture initiatives currently receive government support through subsidies, loans and extension services. These are:

- seasonal tank stocking
- cage culture in perennial tanks (hapa rearing of *O. niloticus* and carp fry to fingerling)
- fry to fingerlings and food fish culture in ponds

Most aquaculture research undertaken has not, until recently, adopted an explicit poverty focus (Ariyarathne, 2001; Pushpalatha, 1999), which focus on the feeding and participatory rearing of hatchery produced fry to large fingerlings with the intention of promoting this to rural fishing communities. This potential for this type of system to contribute to poverty alleviation is high as multiple short production cycles increase cash flow to producers. However, there are some constraints to this approach in the Sri Lankan context. Firstly, the demand for fingerlings to supply pond culturists or seasonal tanks is not yet established. The stocking of seasonal tanks is difficult to sustain in practice as they are used for multiple purposes and irrigation and bathing is prioritised amongst users (Murray, 2004). Secondly, reliable and timely supply of carp fingerlings is unproven. Markets for carp are likely to face intense competition from the cheap, and preferred, tilapia from the tank fishery (Murray *et al*. 2001).

An increasing interest in stocking seasonal tanks and household managed ponds may be related to research that found that enhancing production from perennial tanks larger than 750 hectares by stocking is ineffective (Amarasinghe, 1998). This has resulted in a shift in focus to stocking fish in smaller, farmer-managed, seasonal tank systems (De Silva, 2000). However, social and institutional constraints coupled with seed supply difficulties have proven considerable constraints to such developments. In attempting to tackle the issue of seed supply the government has promoted fry to fingerling rearing in ponds amongst farmers in the Mahaweli System H area. Fisheries societies have also been targeted for fry to fingerling rearing, using large hapas installed in perennial tanks (Pushpalatha, 1999).

Pond aquaculture

Initial interviews with pond farmers supported by a further study (Wijeratne & Brugere, 2001) indicated that pond farming of both fingerlings and food fish has also been constrained by inadequate fry supply from government hatcheries and was not economically feasible once subsidies were removed. Opportunity cost of land use was also identified as a significant constraint to the development of pond aquaculture (Pushpalatha, 2001). Broader findings indicate uncertainty in market demand for carp in the North-western Province and even in urban areas where consumers prefer marine fish (Murray *et al*. 2001).

Seasonal tanks

Given that seasonal tank stocking has not been established as a viable activity (Murray, 2004), the government strategy appears to be stimulation of demand through availability of inputs. The long term benefit and sustainability of this approach has yet to be ascertained. Issues with resource management coupled with an uncertain demand for carp, and a perception amongst consumers that fish originating from seasonal tanks are inferior in quality due to off-flavours, are considerable constraints (Murray, 2004).

Stocking in perennial tanks

Restocking fingerlings raised from small fry in hapas within the perennial tank to augment the existing capture fishery in medium to large size irrigation tanks is also questionable. The species reared in hapas are often a mixture of available carp species and *O. niloticus* supplied by government hatcheries. Stocking perennial tanks with carp fingerlings has proven uneconomical due to low recapture rates (Amarasinghe, 1998). It is believed that this is due to the morphology of the resources and the difficulties in their effective harvesting.

O. niloticus readily hybridises with *O. mossambicus* (De Silva *et al.*, 1999; Amarasinghe & De Silva, 1996). The fecundity of hybrid tilapias is often reduced and resultant populations shown to be male dominant (Hickling, 1971) which, it is hypothesised, could lead to a decline in fish yields in perennial reservoirs (Amarasinghe & De Silva, 1992). Therefore it is likely that stocking a few thousand *O. niloticus* fingerlings into medium to large perennial tanks with an existing self-recruiting and hybridised population will have relatively little impact on production.

Previous top-down attempts at aquaculture development have failed to be sustained after the removal of government support. Full cycle cage aquaculture of food fish for the domestic rural market, attempted in the 1980s, did not prove economically viable. It was constrained by high input costs (supplied with subsidised commercial feed and imported cage materials) and low marketable value due to competition from low cost tilapia from inland fisheries (Muthukumarana & Weerakoon, 1986; Thayaparan *et al.* 1982; Wannigama & Weerakoon, 1982). Other aquaculture using indigenous and high value species such as *Labeo dussumieri* and snakehead (Balasuriya, 1982) failed to yield acceptable results for extension and has not been revisited as a viable option for aquaculture development. Heavy dependence on external inputs and subsidises can reduce the sustainability of aquaculture. The cage culture system tested in the 1980's (Thayaparan *et al.* 1982) inappropriate for the poor due to the high entry costs associated with imported aquaculture goods coupled with the fact that the system creates no economic advantage for producers

1.11.3 Mahaweli System H, North Western Province

The North Western Province selected for the study is characterised by its abundance of irrigation tanks. Mahaweli System H is located within the Kala Oya basin in the country's dry zone. The system runs from East to West originating from the large Kalawewa tank which has a total command area, i.e. that which it irrigates, of 31, 559 hectares. Water availability in the system relies on the supply of water to the Kalawewa tank, which is in turn dependent on the Victoria Reservoir, an important hydropower scheme. Two types of tanks are present within the geographic area which differ considerably in their hydrology. There are 'seasonal' tanks which are rain-fed, usually farmer-managed, minor irrigation schemes and 'perennial' tanks which are chiefly engineer-managed irrigation schemes. It is the network of larger perennial tanks that were selected as the focus of this research. The smaller seasonal tanks were the focus of a related study (Murray, 2004) covering the potential for aquaculture intervention in the smaller seasonal tanks of the same geographical area.

The Mahaweli System H scheme (Figure 1.4) was created through the Government's Mahaweli Development Programme (MDP) in 1975 although the history of irrigation schemes within the dry zone dates back more than 2000 years (Godaliyadda *et al.* 1999). The MDP was intended to resettle families to alleviate increasing landlessness and population pressure for inhabitants of the country's wet zone (Weligamage, 1999).

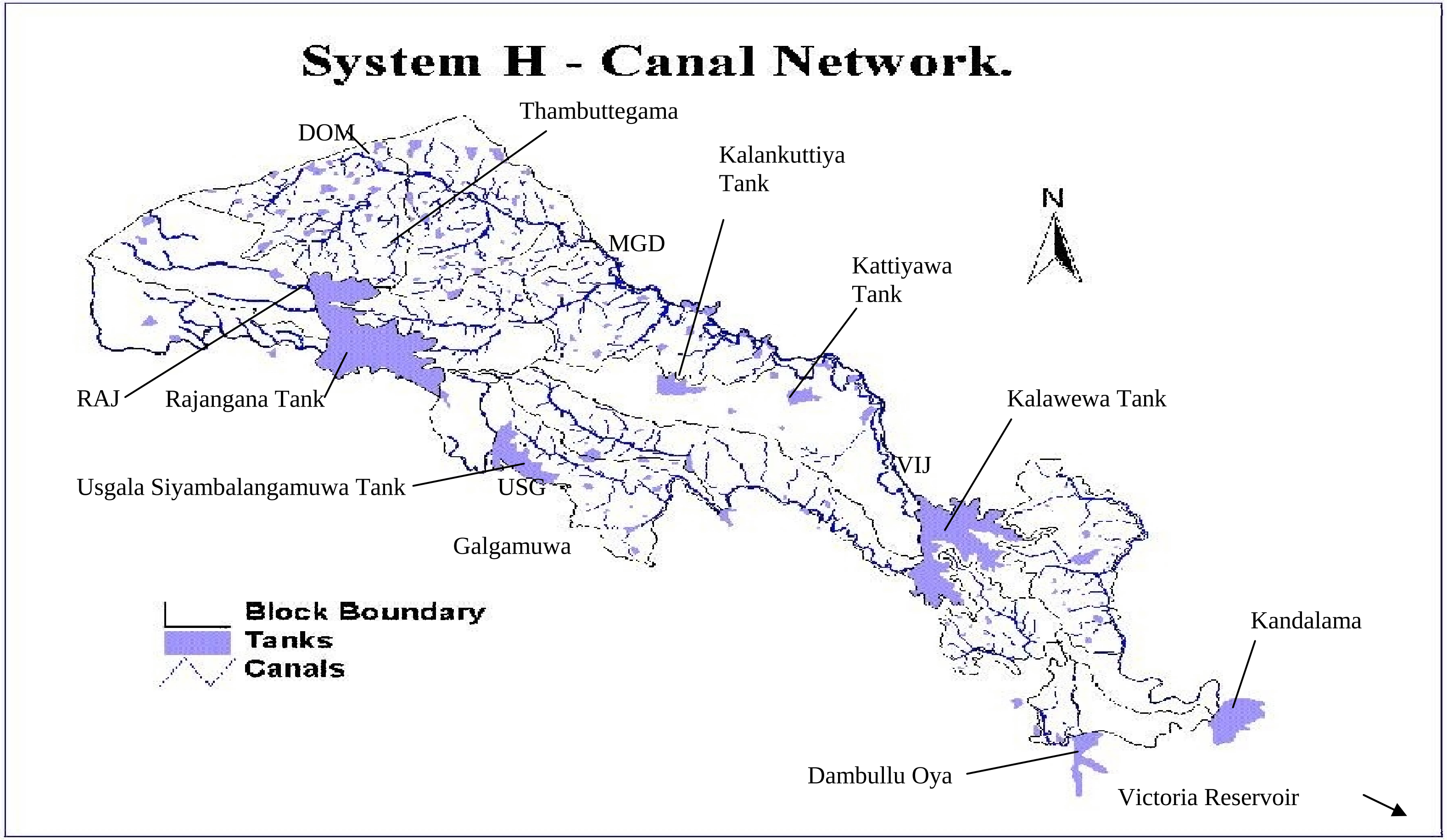

Figure 1.4 Map of Mahaweli System H Irrigation Scheme (Reproduced from Wijeratne & Brugere, 2001).

New settlers received an original one hectare (approximately 2.5 acres) of irrigated paddy land and 0.2 hectares (approximately 0.5 acres) of homestead land. Within Mahaweli System H 31, 800 families were resettled in 1975 to undertake cultivation. Services such as local schools, hospitals and infrastructure were developed in conjunction with the resettlement process. Today two types of villages exist within the area which are referred to as "traditional" villages, consisting of farmers under traditional land tenure systems, and resettled "Mahaweli" villages. During the original plans for Mahaweli System H, water requirements were underestimated (Brugere, 2002) and, as a result, a system of *bethma* cultivation is enforced. This system dictates that just 50% of the land in the command zone is cultivated during the *yala* season as a water conservation method. As a smaller area is irrigated, farmers with irrigated land during this period must permit another farmer to cultivate half of their land. During *yala* dry crops such as chillies and big onions, with a smaller irrigation requirement than paddy are normally planted. These crops have been produced in bulk and farmers have found them difficult to sell. Cheap imports of onion from India facilitated by the government's trade liberalisation policy, have added to farmers' marketing woes (Kodithuwakku, 1997).

Tank classification

Perennial tanks within the irrigation scheme have been classified into different categories. Within System H the majority of larger tanks are under the jurisdiction of the Mahaweli Development Authority with the exception of a few which are still managed by the Irrigation Department. The Mahaweli Development Programme of 1975 rehabilitated tanks and created feeder canals between tanks to improve delivery and control of irrigation supply.

There remains some debate over the classification of system and non-system tanks. “System” tanks have been classified as those receiving water from an upstream tank, usually via a feeder canal connection, thereby permitting improved management by controlled water release to downstream tanks via sluices and the feeder canal network. There are, however, some classified “non-system” irrigation tanks such as Usgala Siyambalangamuwa and Rajangana tank, although not connected by a feeder canal, they still receive a significant inflow of water from system H due to tank spills, drainage and field runoff. Other classifications centre on the number of cultivation seasons the tank can support. CPREEC (2004) classifies system tanks as retaining run off from a catchment area to help farmers to raise more than one crop. They classify non-system tanks as those dependant entirely on rainfall which can support only one crop. Within Mahaweli System H, Usgala Siyambalangamuwa and Rajangana tanks are partially dependent on the other “system” tanks for a significant proportion of their inflow and they should be classified as system tanks as they are both connected to other tanks and, like most other perennial tanks in the area, help farmers to cultivate paddy for two seasons each year.

Fishing within Mahaweli system H has become increasingly important as farmers seek to reduce their dependence on less profitable cultivation and supplement their income. Many have now undertaken fishing as a full or part-time occupation. There remains a high demand for fish within the rural areas of the North western Province and this was comprehensively investigated by Murray (2004) and Murray *et al.* (2001). These studies have concluded that tilapia is the main species consumed within the area, supporting the majority of households’ animal protein requirements in Mahaweli System H.

1.11.4 Researchable issues

Investigating the opportunities and constraints to developing a bottom-up, poverty-focused approach to technical aquaculture systems for use in the delivery system is one research focus of this thesis. The feasibility of selecting appropriate culture systems with a low entry cost to make them accessible to poor producers is also a key objective. The fact that there is currently no established aquaculture, with the exception of the ornamental fish industry in Sri Lanka, indicated that no ancillary services supplying aquaculture inputs existed to any great degree in rural areas. This presents a significant constraint to aquaculture implementation within the Sri Lankan context but also considerable opportunity to investigate a new approach to aquaculture development and further understand the reasons why aquaculture has not been successful within this context.

The assumption that people were willing to take a risk and invest their time and labour through on-going participation in a new activity such as aquaculture also required research as this assumption may be wholly inappropriate for residents of large-scale irrigation systems with other livelihood activities to fulfil. Examination of the constraints to participation is just one facet of this. The impact of aquaculture on the livelihoods of participants within large-scale irrigation systems is important to understand as this will inform further action on promotion of the technologies. Studying the adoption or rejection of new technologies and the rationale for household decisions made in relation to aquaculture will be crucial to establishing the degree of sustainability one may expect from the intervention. Constraints must be identified as well as areas that provide scope for development.

This thesis seeks to examine how poor communities in water stressed areas of Sri Lanka can be engaged in aquaculture research, their rationale for doing so and to what extent aquaculture can improve productivity from the aquatic resources of irrigation systems whilst having a positive impact on livelihoods.

1.11.5 Research framework and timeframe

The research for this thesis was conducted within the wider scope of the DFID-funded project KAR R7123 "Integration of Aquaculture within Large-Scale Irrigation Systems". This was an inter-disciplinary project conducted across two irrigation schemes in Tamil Nadu, India and Mahaweli System H, Sri Lanka. The project sought to investigate the nature of poverty around irrigation schemes in each country and identify potential technical options where the poor could participate in aquaculture within existing irrigation structures. As part of an inter-disciplinary approach, hydrological/ irrigation engineers, socio-economists/agronomists jointly evaluated the potential for, and constraints to, aquaculture in both cases using a systems approach to provide a broad overview of the situation and identify key primary and secondary stakeholders. At the time of fieldwork for this thesis project related work in India ran concurrently, although technical interventions could only be undertaken seasonally as water delivery permitted. The research framework is presented in Figure 1.5 which indicates the processes and individual research activities undertaken between November 1999 and October 2002 in Sri Lanka alone. Appendix 1 contains the logical framework of the project within which the research contributing to this thesis has been undertaken and the wider contribution of this work to understanding the potential of pro-poor aquaculture in irrigation systems.

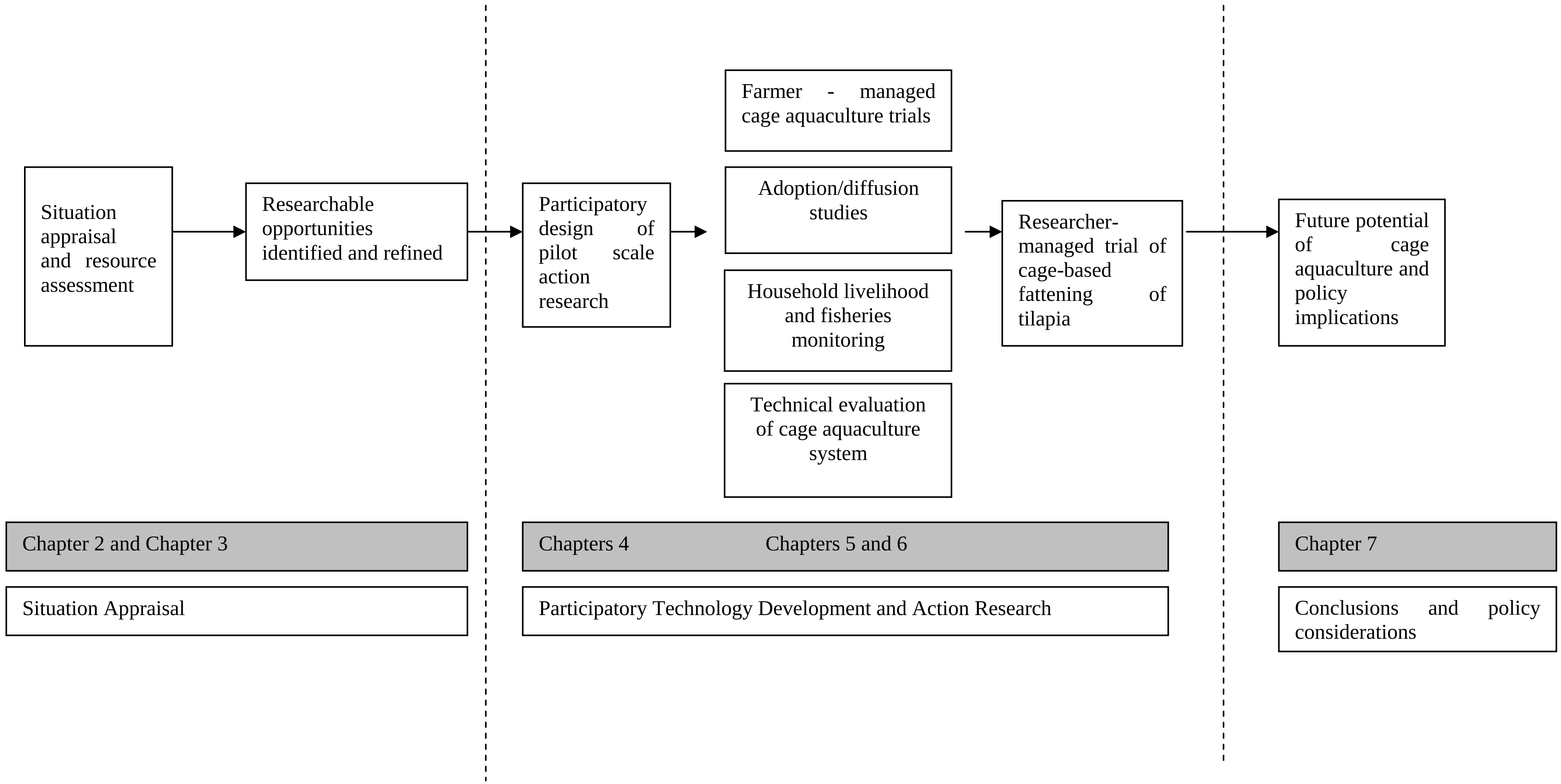

Figure 1.5 Research framework

1.11.6 Outline of the thesis

This chapter commenced with a review of the world freshwater situation against a backdrop of increasing population and increasing water abstraction. It has set the context in terms of the threat of water scarcity and highlights the need for more efficient use of water for food production. This chapter has discussed the limited knowledge of aquaculture within large, engineer-managed, irrigation systems in the semi-arid tropics and in particular the limited knowledge of where there are demonstrated benefits for the poor. A review of aquaculture within irrigation systems is provided with the advantages and disadvantages of several systems outlined and the opportunities for research to address the pressing need to increase food production from water efficiently, with particular reference to improving the livelihoods of the poor.

From this point, in the coming chapters, the process aspects of the research are developed; appraising and identifying suitable communities with which to work, developing working groups of participants and the process of participatory technology development around which the main body of work then centres. This begins in Chapter 2 which provides an overview of the current livelihood situation in several villages in North Western Province, Sri Lanka. Following a livelihoods-approach a summary of the key shocks, changes and trends and seasonality contributing to livelihood vulnerability is presented, with more detailed village-level accounts presented in Appendix 2. The information is complemented by a consumer preference ranking which assesses the range of fish species present within Mahaweli System H and the demand for fish within the area.

Following this section, Chapter 3 outlines resource assessment focused on determining the availability of local inputs for aquaculture. Using semi-structured interviewing a comprehensive assessment of local hardware and fishing products as well as materials identified by farmers was conducted. Rice mills, feed traders and fishers were surveyed to assess the availability of feeds for aquaculture. Using this process to complement the information gained in the situation appraisal a tentative aquaculture research agenda was drawn up placing emphasis on the use of local materials to meet an overriding objective of the research – to reduce poverty by reducing seasonally – linked vulnerability.

The methodological process and outcomes of meetings undertaken in two communities in North Western Province are described in Chapter 4. The involvement of people in technology development to ensure that the technical proposal met their needs shaped the research plan, which was the product of these preliminary meetings. Researchers were also sensitised to the realities of field conditions and the challenges that lay ahead in terms of mobilising and implementing an aquaculture research agenda in resource limiting conditions.

Chapters 5 and 6 present the outcomes of the farmer-managed research work; the process of uptake, technical constraints and factors affecting adoption and rejection of aquaculture, set within the complexity of participants' livelihoods. Initial discontinuance amongst participants and their rationale for doing so are outlined in Chapter 5. The adaptive response of farmers and the degree to which cage aquaculture met their household needs was also monitored in both villages selected for the study. Chapter 6 focuses on household socio-economic factors which may have played a role in the adoption process and complements the findings of Chapter 5 as a broader view of livelihoods activities and their relative value is assessed. A number of households in both villages were surveyed using a fisheries and livelihoods questionnaire and key adopter characteristics identified. The fisheries context, an area which was the principal daily income source for households in both communities studied, is also presented as this formed an important linkage with the aquaculture intervention, in terms of input supply and market competition.

Chapter 7 brings together the results from the main body of farmer-managed work in presented in Chapters 5 and 6 and discusses them within the overall context of livelihoods. Particular attention is paid to the reasons for adoption or non- adoption of the aquaculture system especially specific constraints and livelihoods considerations, which may have influenced the process. The benefits of longitudinal study are highlighted in preference to snap-shot analyses of livelihoods and areas of further research needs identified. Specific implications of the findings for future aquaculture interventions and fisheries policy are discussed and, where appropriate, recommendations made.

Chapter 2 Situation Appraisals of Villages in Irrigated Areas of North Western Sri Lanka

2.1 Introduction

Prior to the identification of the study sites and specific researchable issues a stakeholder workshop was held in Kandy prior to research intervention. Present were secondary[1] stakeholders from research institutions, NGOs, local and central government, donors and banks. This meeting was held to introduce the wider DFID project and facilitated an understanding of different stakeholder perspectives. The meeting also served to assess the potential for building partnerships with local organisations. The stakeholders agreed that there was a need for this type of research in Sri Lanka and that it was appropriate for the needs of the country. Stakeholders identified various benefits to their participation but were constrained by their lack of time and resources for active project support. Two key constraints were identified during the process of the workshop; firstly, that there was no real inherent knowledge of inland aquaculture within Sri Lanka and secondly, that the withdrawal of stage patronage for inland fisheries between 1989-1994 had weakened institutional capacity which could further constrain the potential to implement development within the inland fishery sector.

In order to assess whether aquaculture was a viable option for communities around large-scale irrigation systems situation appraisals using participatory methods to

[1] Secondary stakeholders are those who have an interest in the resources affected by an intervention, or are involved in the decision-making or delivery processes of an intervention.

assess livelihoods and resource availability were conducted at selected villages within Mahaweli System H. These appraisals focused on determining if aquaculture was technically feasible as a low input activity that could explicitly contribute to alleviation of poverty at a community level. A sustainable livelihoods approach was used to provide a framework within which a holistic overview of the local context could be obtained. Additionally a specific resource orientated appraisal was conducted to assess local availability of aquaculture inputs. Information gained from both these activities was used to inform a poverty-focused aquaculture research agenda.

2.2 Methodology

Using a livelihoods approach a combination of participatory tools was used to explore individual aspects of livelihood vulnerability indicated within the sustainable rural livelihoods framework. These were largely developed from the work of Townsley (1996), Gosling & Edwards (1995), Pretty *et al*. (1995) and Intercooperation (1993).

Potential research sites were identified from secondary data sources, local maps and consultation with local key informants prior to going to the field. This ensured a more efficient use of time. As the wider project was inter-disciplinary, village selection for the situation appraisal sought to meet the needs of three components – a poverty-focused aquaculture study, but also a hydrological engineering analysis and a socio-economic livelihoods survey.

Therefore initial village selection was based on the following criteria:

- Suitable physical characteristics for the integration of aquaculture within the existing irrigation structures

- Sufficient numbers of households to permit a survey of socio-economic status across 3 wealth categories by the project socio-economist.

A further breakdown in selection criteria for each discipline is outlined in Table 2.1.

Table 2.1 Village selection criteria for interdisciplinary research in Mahaweli System H

Discipline	Researchable issues	Approaches taken	Key selection criteria	Expected outcomes of situation appraisal
Aquaculture	What types of aquaculture have potential for adoption by the poor around irrigation structures? Can aquaculture contribute to poverty alleviation as a sustainable livelihood option for the poor? What are the potential complementarities or constraints to integration of this activity within their livelihood?	Livelihoods 'Soft' systems Multi-disciplinary	Poor population living in close proximity to irrigation structures Sufficiently reliable water supply to practice aquaculture Interest of the communities / sub-section of communities	Identified opportunities and constraints to poverty-focused integrated aquaculture within the canal irrigation systems
Engineering	Can large-scale irrigation systems be managed to accommodate other water uses, including aquaculture?	'Hard' systems Multi-disciplinary	Access to canals, water managers, institutions and user groups. Access to secondary data	Development of model for improved irrigation management.
Socio-economics	Is there a relationship between water availability and livelihood strategies? If so, what livelihood strategies are practiced within the rich, medium and poor wealth categories around irrigation systems?	Livelihoods Multi-disciplinary	Relative differences in water availability. Sufficient numbers of rich, medium and poor villagers. Access to secondary data	Stratified survey groups for livelihoods questionnaire and analysis

Secondary data was obtained from officials at the Mahaweli Resident Project Managers (RPM) office in Thambuttegama. Villages with high proportions of smallholder farmers and / or fishermen were selected as these groups represented the main livelihood types identified within the area. After the initial screening villages were visited. The *Grama Nildari* (GN)[1] office was the first point of contact. Further key informants were subsequently identified by the GN and interviewed about village population, livelihood activities and water resource access and availability and information noted. Transect walks were conducted for orientation and an overview of village resources. Field teams were trained in the appraisal methodologies and practice sessions of participatory exercises to examine changes and trends, seasonality and fish marketing and consumer preferences were conducted at the field office in Galgamuwa. These sessions helped to develop appropriate checklists sensitive to local conditions and livelihoods for semi-structured interviews and timelines, seasonal calendars, focus group interviews and ranking exercises, which are outlined in the following section. On completion of the training sessions field teams visited the target villages and the participatory exercises got underway. Any further improvements and revisions based on experiences from the field were incorporated into the exercises for future field work in the target villages.

[1] The Grama Nildari is a local village administrator responsible for collection of demographic data such as censuses. They also hold a record of state benefit distribution for each household within the village.

Due to several logistical constraints and simultaneous participation on R7123 project work in India, village appraisal was conducted over three phases. Emerging knowledge of the local context and identification of further villages for study also contributed to the process.

Village names are coded for anonymity. The following timescale of appraisals is outlined below:

- November 1999 – Canal-based villages selected: VIJ, MGD, DOM and KAT (a tank-based village) and initial short appraisal of villages around Rajangana Tank

- June 2000 – KAL and USG villages located near Kalankuttiya and Usgala Siyambalangamuwa Tank respectively.

- June 2001 – RAJ village located on Rajangana tank

A map depicting the locations of the villages surveyed is presented in Figure 2.1.

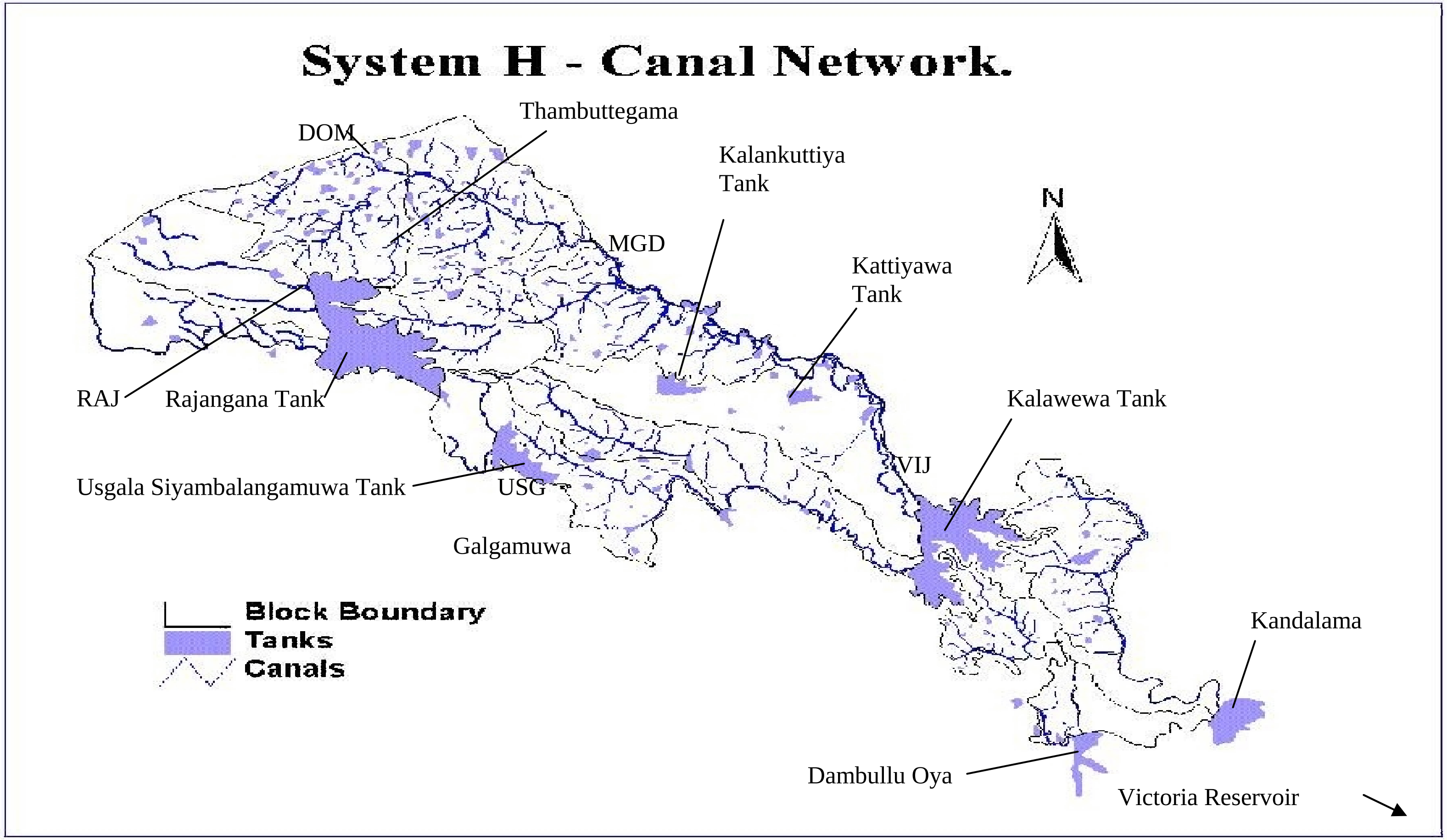

Figure 2.1 Map of Mahaweli System H Irrigation Scheme (Reproduced from Wijeratne & Brugere, 2001).

A key hypothesis of the socio-economic study was that water availability affected relative wealth status. The right bank main canal of Mahaweli System H was selected as this presented an opportunity for hypothesis testing between villages at the head, middle and tail of the canal. From an aquaculture perspective this also presented potential research interest as no aquaculture within irrigation canals of South Asia, particularly Sri Lanka, has been reported in the mainstream scientific literature. Three villages were selected at the head, middle and tail of the Right Bank Main Canal, representing high, medium and low levels of water availability. The village selected at the head of the Right Bank Main Canal, VIJ, was also located on the Kalawewa reservoir, the main storage reservoir that provided water to the Mahaweli H irrigation scheme. The villages selected to represent the middle and tail reaches of the canal system were MGD and DOM respectively. This selection was made to facilitate the socio-economic study with the underlying hypothesis that access to water was a key factor contributing to poverty.

This initial selection, however, did not encompass the abundance of storage tanks which were an important hydrological feature of Mahaweli System H. Consequently a fourth village was selected at Kattiyawa tank. This tank was used by both farmers and fishermen and managed for irrigation purposes by the Mahaweli Development Authority. During the second phase of fieldwork in June 2000 the potential of the large engineer-managed irrigation tanks for aquaculture research received greater consideration and a further two villages located near irrigation tanks (Kalankuttiya and Usgala Siyambalangamuwa tanks) were identified for inclusion in the participatory situation appraisal. This was driven by a growing consensus among the research team that System H's irrigation tanks played a more important role in rural livelihoods than irrigation canals and that overlooking their potential for aquaculture would be erroneous.

An initial appraisal of villages around Rajangana tank in November 1999 indicated complexity in the management of the tank fishery between villages of settled Singhalese fisher-farming communities and encroachers living within the tank reservation land. In addition, Rajangana tank is divided by the provincial boundary between North Central and North Western Provinces. Historical difficulties with enforcement of fishing regulations through the tank's three fishing societies were noted at this stage, as by Watson (1999) during an appraisal of fisheries development in Mahaweli System H. The provincial boundary division exacerbates poor management cohesion as one fishing society deals with the North Central fisheries extension service and the others with the corresponding North Western service. Tenure of land used by encroaching fishing communities was uncertain and the cause of a long running dispute with the Rajangana tank irrigation management. For these reasons communities around Rajangana tank were excluded from the situation appraisal in the initial stages until greater understanding of the tank's relevance to regional fish production had been established. Work conducted by Murray *et al.* (2001) over the same period on fish marketing within the villages in and on the periphery of Mahaweli System H indicated that Rajangana tank was a major source of inland fish production in North Western Province. Consequently, a village on Rajangana tank (herein referred to as RAJ village for anonymity) was incorporated into the system-wide situation appraisal in June 2001 to gain an improved understanding of the characteristics of fishing communities and their livelihoods.

Although Rajangana tank lies on the boundary of Mahaweli System H irrigation institutions do not technically regard it as part of Mahaweli System H. This caused some concern amongst members of the multi-disciplinary team as Rajangana tank's location (to the south of System H and divided by the provincial boundary) and the RAJ community type (fishing only) did not fit within the margins of their research objectives. In hydrological terms Rajangana tank's importance in receiving drainage through surplus irrigation from Mahaweli System H and its capacity to deliver water for 2 seasonal rice crops in the command area (i.e. the area of land which it irrigates) made its exclusion from system tank classification questionable according to the definitions in Chapter 1. Adopting the view that the tank was an important component of the region, and indeed the system, aquaculture researchers selected this community for appraisal in June 2001.

2.2.1 Participatory Methods

Using the DFID Sustainable Rural Livelihoods approach as a framework for the situation appraisal, the vulnerability context of the communities selected was investigated using various participatory tools. Checklists were used to guide the facilitator during participatory exercises investigating shocks, changes, trends in the timelines exercises and seasonality through a seasonal calendar. To ensure that relevance to the local context was maintained, the checklists were prepared and adjusted with the assistance of local field researchers. The role of the observer (outsider) was restricted by the language barrier which constrained direct participation. Table 2.2 provides an overview of the participatory tools used to collect information in each village. Timelines were used to identify the major livelihood shocks experienced from partition (1947) onwards whereas changes and trends were noted over the past 10-20 years. The timelines method used is explained in full in section 2.2.2. Seasonal calendars were used to gauge the importance of seasonality to livelihoods. Detailed descriptions of these methods are outlined further in this section.

Table 2.2 Participatory methods used in the situation analysis

Tools used	Rationale for use
Timelines	Exploring changes and trends in main livelihoods activities, natural resource exploitation, population, social values etc
Seasonal calendars	Mapping seasonal changes in key livelihoods activities, access to resources and goods, household income etc.
Focus group interviews and consumer fish preference ranking	Examination of consumer preferences for fish and fish marketing
Wealth ranking ***(conducted later in the project)***	Establishment of wealth distribution within each village. To identify people to be interviewed for livelihoods analysis for 3 wealth strata
Transect walks	For orientation of the size and status of village. To gain first-hand knowledge of the resource base, agriculture and fishing activities within the village.
Resource assessment	To gain knowledge of the current resource availability and use. Identify possible sources of competition, seasonality and trends and changes in resource supply.

Sources: Townsley (1996), Gosling & Edwards (1995) and Intercooperation, (1993) and Pretty *et al.* (1995)

Further to the examination of livelihood vulnerability, taken as the best indicator of poverty at this stage, focus group interviews were conducted with groups of participants in the study areas to establish the availability of, and consumer preference for, fish.

Townsley (1996) states that:

"In order to develop on a wide scale, aquaculture requires that the marketing arrangements for fish and the demand for the species being produced be well-developed. Where the marketing system is limited and demand for fish is not strong, aquaculture is likely to remain a relatively marginal activity. Assessment of the market is therefore a critical part of the overall assessment of the feasibility of aquaculture."

Acknowledging the role of market demand for fish and its potential impact on aquaculture, information was collected about rural fish marketing in Sri Lanka. This was achieved by reviewing available secondary data in Murray *et al*. (2001) and Little *et al.* (2000) and by primary data collection with fish consumers and vendors. The method for the latter is outlined in section 2.2.2.

Local resources with potential use in aquaculture were also assessed. This was largely achieved by semi-structured interviewing of fishers, hardware stores, rice millers, poultry feed suppliers and other retailers in villages and in Galgamuwa town. This area is the focus for Chapter 3 where the opportunities for aquaculture identified in this phase of situation appraisal are reflected upon.

2.2.2 Methodological details

Transect Walks

Transect walks following the method described in Townsley (1996) were carried out in each location. Key informants such as farmers and fishermen were interviewed informally whilst on the walks and any problems or conflicts arising from resource use or livelihood activities noted.

Timelines methodology

The timelines exercises were disaggregated by gender to highlight any apparent differences between male and female perceptions of changes and trends. This disaggregation facilitated crosschecking of information. Groups consisted of mixed age in an attempt to minimise generational bias. A minimum of five participants was recruited from local households or meeting areas by key informants for each replication of the exercise. The key shocks, changes and trends affecting local livelihoods were discussed in the timelines exercise. Many of these variables were pre-selected in accordance with key factors affecting vulnerability identified in the DFID S.L. Framework (DFID, 1998) modified to account for local variations through the input and guidance of local partner researchers. The shocks, changes and trends identified by field teams and researchers in the preparatory phase and subsequently investigated are represented in Table 2.3.

During the timelines exercises participants were reluctant to write on the paper. This was perhaps due to lack of familiarity with pens or simply shyness as the writer was often the focus of attention. Children were encouraged to adopt this role in order to overcome the problem. When there were no volunteers to write, the local facilitator used the pen to note key events, changes and trends in the Sinhala language. A trade-off between optimal participation and efficiency of information gathering had to be made. At the end of the discussion the materials used for the timelines (pens and paper) were left in the village with the participants and normally distributed among their households.

Table 2.3 Key shocks, changes, trends and seasonality variables investigated

	Sector of Vulnerability Context		
	Shocks	**Trends and Changes**	**Seasonality**
Variables investigated	Human health (epidemics, hunger periods etc.) Natural shocks (droughts, floods etc.) Livestock disease Crop failures Economic shocks (sudden variations in prices, unemployment periods etc.) Conflicts (between landowners and landless, between irrigation authorities and farmers and others) Other important technical and social events (e.g. introduction of mechanised farming, construction of wells/bore-wells, water supply, introduction of TV and telephone in the village)	Changes in main income sources, emergence of new income generating activities Agricultural production (types of crops) and related changes in the type of tasks carried out, impact on diet, fertiliser and pesticide use, impact of mechanisation and irrigation. Marketing of different foodstuffs, access to markets, prices of foodstuffs and consumer goods. Access to and use of natural resources, including water, fisheries, wood and fodder, changes in bio-diversity and impacts on daily life. Population changes, including migration, family planning, village size, % landowner-landless. Ways in which life has improved or worsened, including consumption trends, health, education, standard of living, family values, infrastructures (transport, hospital), savings behaviour.	Prices of food items important in the household diet (variations in prices also indicating the availability and production (i.e. harvest time) of these foods). Meal consumption frequency disaggregated by age. Water availability in canals, tanks and other local water resources. Work load and opportunities for employment, with distinction being made between younger adults and elders. Health (incidence of disease). Household expenses (religious festivals, school uniforms and books.). Availability of fodder and fuel wood. Access to markets and other infrastructures.

Seasonal calendar methodology

The influence of seasonality was investigated using seasonal calendars to map seasonal variation in availability of key variables outlined in Table 2.3. Seasonal calendars were established with participants who were randomly recruited from local households and meeting areas. The groups were of mixed ages and exercises conducted separately with men and women. Calendars were prepared by making a large matrix with the months of year written across the top and the seasonally affected variables written down the side. All text on the calendar was written in the local language so that participants could follow the discussion visually. A limited number of beans were allocated by participants to represent availability or relative price, 0 = no availability, 1 = low, 2 = medium up to a maximum of 3 denoting high availability. Upon completion of the exercise, the beans and seeds were left with the participants. The results of the seasonal calendar exercise were combined with those of the timelines exercise to provide a broad overview of factors influencing vulnerability at the village level.

Approximately two days were taken in each community for orientation and to complete participatory exercises.

Transforming Structures and Processes.

To a lesser extent transforming structures and processes, such as laws, government policy and the role of cultural norms, were investigated as part of the situation appraisal through discussion with focus groups of local fishers and fisher-farmers. The Ministries of Fisheries and Aquatic Resource Development (MOFARD) and the National Aquaculture Development Authority (NAQDA) of Sri Lanka were visited to collect policy and planning documents relevant to inland fisheries and aquaculture. Many of these stakeholders were present at the meeting in Kandy therefore a broad understanding of the current situation was gained through the stakeholder workshop process.

The availability of local structures, such as financial institutions, markets and community organisations, was investigated through discussion with local key informants and triangulated with others met on village walks. Cultural norms were discussed with local researchers who had a detailed knowledge of local cultures within the rural areas surveyed. Access to resources and factors affecting such access were discussed with local people throughout the course of the appraisal.

Demand for fish and consumer preference

In order to assess the importance of fish to rural households in the selected villages focus group interviews and ranking exercises were conducted. These methods were also used to provide an insight into the status of the local fishery and fish supply. This approach aimed to highlight any marketing and consumer preference constraints to aquaculture identified by Townsley (1996) as possible constraints to sustainable aquaculture.

Focus group interviews were conducted with small groups in each village. A minimum of four participants was sought in each case to facilitate discussion and permit crosschecking within the group. In some cases up to ten participants were engaged in the focus group discussion. To enable comparisons to be made groups were interviewed in a semi-structured manner, based around a checklist. A minimum of three groups was targeted in each village to facilitate triangulation and crosschecking of information.

In each village a fish preference ranking exercise was undertaken. Cards with fish names were prepared prior to interviewing respondents with new cards prepared in response to new species cited by the group. The most important fish species were identified at local markets prior to field interviews. From the prepared cards the respondent group were asked to identify the fish that they recognised and that were available and then rank them in order of preference. Positive and negative aspects of the each fish species were noted as well as the local price. Semi-structured interviewing was used to discuss the status of the local fishery (where applicable) and to ascertain the frequency and quality of the fish supplied to the village. This provided an overall account of fish availability, consumer preference, fish price and positive and negative trends in the local fisheries. This information was critical to establish whether there was likely to be a market demand for cultured fish and at what price it would be competitive against the existing fish derived from the capture fishery of the tanks.

2.3 Results

The results presented are summarised from case studies of each village appraisal. As sizeable and detailed amounts of information were yielded at each village, details of village - level livelihood case studies and how they relate to aquaculture intervention are presented in Appendix 2. Results of timelines and seasonal calendars provide a broad overview of the vulnerability context of households in the villages surveyed.

Results of focus group interviews and ranking exercises depict consumer preference within the villages studied. Key features of local marketing analyses conducted by Murray (2004) in North Western Province are presented to complement the consumer preference results providing a broad overview of the market demand for fish in both contexts.

2.3.1 Transect walks

A transect of USG village is presented in Figure 2.2 to indicate the information gained from this exercise.

Area	Jungle	Paddy Fields	Main village	Shops and main road	Cattle grazing	Tank
Activity/Use	Slash and burn agriculture Collection of wild bee honey Illegal forestry	Cultivation of rice in Yala (50% are cultivated under *bethma* system) and Maha	Settlement of painted mud or brick houses. Homestead area typically 0.2 hectares. Home gardens frequently planted with curry leaves, chilli, tamarind trees and coconut trees. In some with border crops of teak or kapok trees.	Access to Galgamuwa and Meegalewa (1 bus per hour) Small shops selling local produce and dried goods. Agricultural inputs such as pesticides also sold.	Open access grazing on grassy banks of tank. Increased grazing area when tank water level low (Apr. - Sept.).	Fishing Irrigation storage Bathing Laundry Livestock watering Vehicle cleaning
Problems	Depletion of forest resource Illegal logging	Increasing frequency of elephant damage to rice and *chena* crops possibly due reduced jungle habitat.	Increasing population led to construction of new fishing village. Conflicts due to government subsidy of Rs. 50 000[1] to new homebuilders.	-	Cattle theft. Cattle tethering to avoid conflict caused by livestock straying into home gardens and crops	Widespread illegal fishing practices Difficulties in resource regulation by NAQDA

Figure 2.2 Transect walk in USG village June 2000

[1] 1 US $ = 83 Sri Lankan Rupees (Source - http://www.oanda.com/convert/fxhistory/ Time period = 01/01/00 to 01/07/02.)

The transect walk presented for USG typifies characteristics experienced in the other tank based communities studied. It indicated that the main income generating activities were agriculture, fishing and some livestock rearing. The principal income sources in MDG (middle, canal) and DOM (tail, canal) remain agriculturally - based due to the lack of access to a perennial tank. In other communities many households have diversified into other off-farm income generating activities, the most important of which is fishing. The tank reservation land or the tank land when it recedes is also used for cattle grazing and could be classified as an open access resource for this purpose as there are neither legislation nor community norms restricting access for this activity. Exploitation of the natural resource base also occurs in the forested areas where younger men undertake illegal timber extraction. Agriculture in the irrigated command area under the tank is restricted to paddy cultivation due to the water issues largely determined by the Irrigation Department. Farmers are compelled to cultivate paddy. In the *Yala* season cultivation occurs under the *bethma* system where only half the land is irrigated and farmers have the right to cultivate 50% of another farmer's land. *Chena* cultivation (slash and burn agriculture) has been outlawed by the government due to deforestation which has resulted in reduced earning potential for some farmers who adhered to the law, however, others continue to cultivate crops such as cereals and pulses as well as some dry-land vegetables.

2.3.2 Vulnerability context

The impact of shocks, changes and trends to livelihoods was investigated in seven villages. Key areas of similarity are presented. Detailed study outcomes and their impact on potential aquaculture interventions are presented in Appendix 2.

Shocks

A timeline was used to orientate and annotate some of the key livelihood shocks experienced. An example of a timeline for USG village is presented in Figure 2.3 indicating shocks reported by respondents during the situation appraisal. Extreme water shortages were reported in several villages. In the villages of MDG, DOM, KAL, USG and RAJ drought conditions causing crop failure and for many farmers, entrapment in a cycle of debt were reported during the 1970s. System H irrigation water first became available in USG village in 1976 and by 1983, after completion of the irrigation development scheme, Mahaweli drainage water was received by Rajangana tank. Mechanised farming was introduced in the villages during the 1970s and 1980s and this reduced the traditional labour requirement for cultivation. In 1982 the Ministry of Fisheries provided subsidies for boats to fishermen at VIJ (Kalawewa tank) and RAJ village (Rajangana tank) fishing villages in a bid to increase exploitation of, and consequently production from, inland fisheries. More recently, government economic policy of trade liberalisation and deregulation has caused a drop in the chilli price due to competition from cheap imports from India. A similar situation occurred in 1999 with onion imports from India causing local prices to drop which negatively affected farmers' ability to sell their produce. These shocks appeared to increase household vulnerability as produce was not only left unsold and spoiled but many farmers remained in debt as they had borrowed inputs, such as fertiliser and pesticides, from local shop owners and money lenders against their harvest profits.

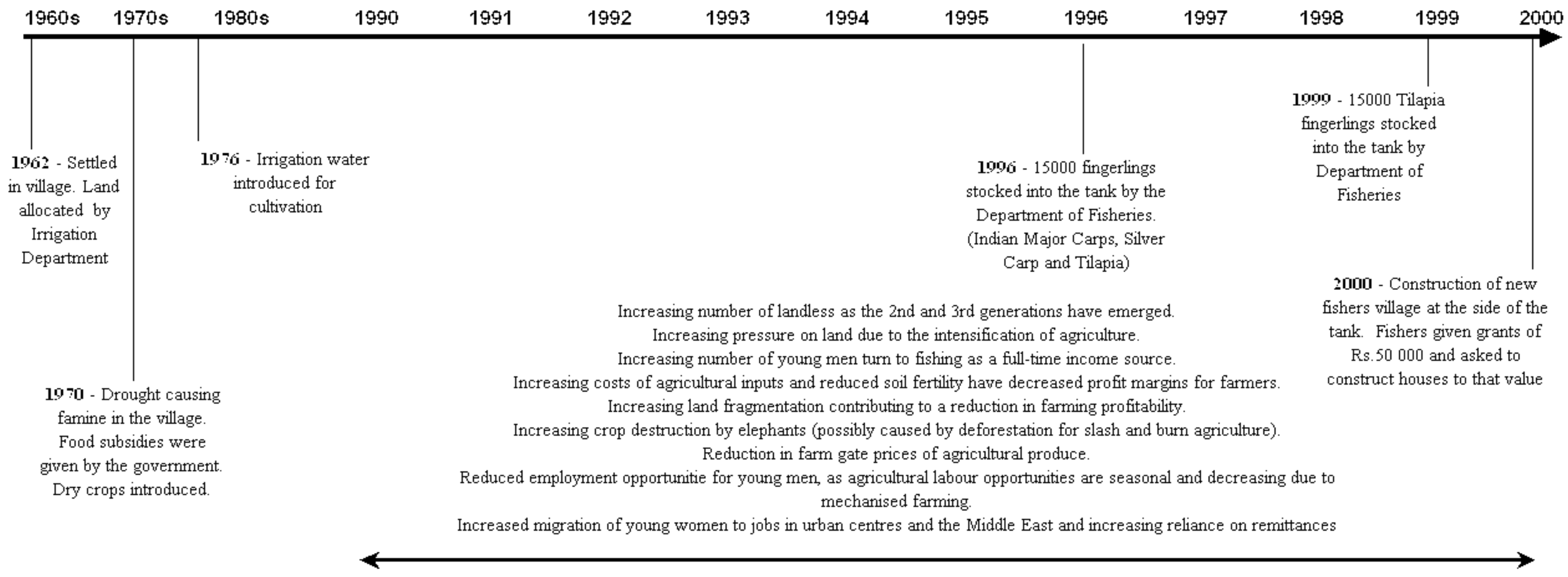

Figure 2.3 Representation of a timeline depicting shocks, changes and trends identified by male and female[1] participants in USG village (June 2000).

[1] No substantial differences between male and female groups were noted at USG village.

Changes and trends

The major changes and trends reported were in the types of livelihood activities undertaken. With the exception of the fishing communities at VIJ (head, right bank main canal and Kalawewa Tank) and RAJ village (Rajangana tank) many respondents reported an increase in part - time fishing to supplement incomes from farming. The main reasons cited for this were decreasing profit margins from agriculture caused by land fragmentation coupled with escalating input costs. In addition, the emergence of under-employed landless second and third generations led to more men undertaking fishing. Fishing was a far less important livelihood option in the canal-based communities of MDG and DOM, whose livelihoods remained predominantly agriculture. This was accounted for by the limited access to tanks in the surrounding areas where all other villages surveyed were well endowed with access to tank resources.

Land fragmentation was caused by the emergence of second and third generations of families in both settled and traditional villages. Farmers reported a shift in the types of crops cultivated to production dominated by paddy and some other food crops (OFC) such as chilli and big onions. Agrochemical consumption had increased due to a shift away from traditional rice varieties to higher yielding, modern, varieties requiring greater applications of agrochemicals. Pesticide use had increased due to increased accessibility and tied lending arrangements between suppliers and farmers. Low farm gate prices for rice had failed to offset the rise in production costs to maintain profitability, making the overall cultivation system less profitable overall.

Decreasing local employment opportunities for young people were found to have led to an increase in out-migration for employment in urban areas in garment factories by young women or the Sri Lankan Army for young men. Some men migrated to the Middle East for employment as drivers or domestic helpers attracted by the relatively high salary and potential to save or send earnings back to their families. Increasingly women undertake work in the Middle East as housemaids or cleaners. Some male respondents in KAL felt that this trend was leading to social disharmony amongst female returnees as "women found it difficult to return to village life after their experiences overseas".

Negative changes and trends in fisheries were reported in all fishing communities. Commonly stated was the increased number of entrants to the fishery, decreasing individual daily catch volume and decreasing average size of fish caught. Over the past twenty years, about which respondents were interviewed, the prevalence of indigenous carp species such as *Labeo dussimieri* in the catch has diminished and the catch is now dominated by tilapia.

Seasonality

A typical seasonal calendar is shown in Figure 2.4. The influential effect of seasonality is largely connected to the monsoon rainfall. There are two cultivation seasons dependent on sufficient rainfall to fill storage tanks and provide irrigation water for crops. Key informants indicated that the *maha* (October to March) cultivation season is the most important paddy cultivation season. At this time, irrigation is provided in part from storage tanks. However, demand for tank irrigation water during the growing season is lessened due to the effect of localised rainfall in the command area. During the *yala* cultivation season rainfall input from the monsoon is less significant. Smaller areas of land are cultivated for paddy and the system of *bethma* cultivation takes place. Dry crops such as chilli, onion, okra, sesame and bringal are planted during this season. Timing of water releases and the type of crops cultivated determine the labour input required. Agricultural labour demand peaks during land preparation and harvesting periods. Shared labour and in-migration of family members from other villages is common during at this time. This leads to increases in household expenditure, but this practice is still cost efficient compared to use of paid labour. Food prices were relatively higher during the cultivation season and decreased after harvest due to the abundance of produce reaching the market at this time. Harvested paddy is initially sold in settlement of loans for agricultural inputs. Once cultivation debts are repaid the remainder is stored for household consumption, hence a household's capacity to cultivate paddy has an important role in household food security. This situation was not found at RAJ village as there was no paddy cultivation and households relied entirely on purchased rice and other produce increasing their vulnerability through increased sensitivity to market forces in the food sector.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fish Price	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●●
Rice Price	●●●	●●●	●●	●●	●●	●●	●●	●●	●●●	●●●	●●●	●●●
Chilli Price	●●	●●	●●	●●	●●	●●●	●●●	●●●	●●	●●	●●	●●
Dhal Price	●●	●●	●●	●●	●●	●●	●●	●●	●●	●●	●●	●●
Coconut Price	●	●	●	●●	●●	●●	●●	●●	●●●	●●●	●●●	●●●
Other Meat Consumption	●	●	●	●●	●	●●	●	●●	●●	●●	●●●	●●●
Fish Consumption	●●●	●●●	●●●	●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●	●●●
Fish Catch	●●	●●	●●	●	●	●	●	●●	●●	●●●	●●●	●●●
Large Tilapia Availability	●	●	●	●	●	●	●	●●	●●●	●●●	●●●	●●●
Small Tilapia Availability	●●	●●	●●	●●	●●●	●●●	●●●	●●●	●	●	●	●
Bad Weather Conditions	●	●	●	●●●	●●●	●●●	●●●	●●●	●●	●●	●●	●●
Tank Water Level	●●●	●●●	●●●	●●	●●	●●	●	●	●	●●	●●●	●●●
Fuelwood Availability	●●	●●	●●	●●	●●●	●●●	●●●	●●●	●	●	●	●
Fish Drying Activity	●	●	●	●	●●●	●●●	●●●	●●●	●	●	●	●
Transport	●	●	●●●	●●●	●●●	●●●	●●●	●●●	●●	●	●	●
Access to markets	●●●	●●●	●●●	●●	●●	●●	●●	●●	●	●	●	●
Employment Opps.	●	●	●	●	●●	●●	●●	●●	●●●	●●●	●●●	●●●
Health Problems	●	●	●	●	●	●	●	●	●●	●●	●●	●●
HH expenditure	●●●	●●	●●	●●●	●●	●●●	●●	●●	●●	●●	●●●	●●●

Figure 2.4 Schematic representation of a seasonal calendar at RAJ village (men's group) 1 dot = low, 2 dots= medium, 3 dots = high

Access to the town *pola*[1]was considered to be adequate for most of the year. During the *maha* monsoon, around November, most villages reported some disruption to transport links caused by flooding and damage to roads.

Fishing seasonality appeared to contribute significantly to household vulnerability. The impact of seasonality in fisheries varied from tank to tank according to fluctuations in water level and fisheries management practices. Weather conditions also determined the number of days that fishing takes place and catch per unit effort (CPUE) although this required further verification. Fishing appeared to be adversely affected as water levels increased, with the exception of both Usgala Siyambalangamuwa and Rajangana tanks where increasing water levels were reported to initially enhance catches, particularly of large fish at the onset of the monsoon rain in November. In tanks such as Kalankuttiya, Kalawewa and Kattiyawa, fish catches reportedly decreased during periods of high water levels (large tank water spread area). During the *maha* monsoon catches in these tanks were reported to increase during the summer months as tank water levels decreased. Table 2.4 illustrates the variation in reported periods of high and low catches in each tank. In addition to seasonal variation catch volumes were found to be highly variable between fishers reflecting factors ranging from differences in gear type and number used to skill and fishing method (passive or active – see Chapter 5). Usgala Siyambalangamuwa and Rajangana tank fisheries appear to exhibit different seasonal catch patterns when compared to so-called 'system tanks'. Communities around Kalawewa, Kattiyawa,

[1] *Pola* is the local term for the weekly market held in the town. Eppawela, Thambuttegama and Galgamuwa were the nearest locations for *polas* in the villages studied. Local produce is bought and sold in these market places by travelling vendors who operate markets from town to town within the district.

and Kalankuttiya exhibited a more simplistic seasonal effect directly related to water levels; high catches when the water levels are low and low catches when they are high. The situation appears more complex in Usgala Siyambalangamuwa and Rajangana tanks which follow a more varied pattern across the year.

Table 2.4 Seasonality of fish catches in village surveyed during the situation appraisal.

			Month											
Village Name	**Tank Name**	**Relative Importance of Fishing**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
VIJ	Kalawewa (S)	High amongst Muslim community												
KAT	Kattiyawa (S)	Moderate												
KAL	Kalankuttiya (S)	Moderate												
USG	USG Siyambalangamuwa (NS)	High												
RAJ	Rajangana (NS)	Very high												

LOW **VARIABLE** **HIGH**

In addition to seasonal variability in catch volumes changes in catch composition were also discussed in focus group interviews. Fishers at Rajangana tank noted seasonal variations in the size of tilapia caught and highlighted that during the onset of the monsoon rains in November, larger tilapia, carp and snakehead are caught. This period of increased catches tended to subside as the water levels increased further. Little seasonal variation in catch composition was reported in Kalankuttiya tank. The catch of eels was reported to increase during the *maha* season in Kattiyawa tank. Fishers at VIJ village reported that the range of species in the catch increases as fish became easier to catch as the water level in Kalawewa tank decreases during the dry season. Key informant interviews in DOM village also reiterated this view.

Respondents in MDG, with no resident fishing community, who were served by fish cycle vendors reported that eels were more available in the dry season.

2.3.3 Fish availability and consumer preference

Actors within the system

Fish marketing within Mahaweli System H is dominated by the activities of a series of small bicycle and motorcycle fish vendors. These vendors operate as self-employed distributors. In most tanks the majority of vendors modify their bicycles to accommodate a wooden box. This keeps entry costs for fish vending down and is part of the attraction of the activity. Fish is caught by artisanal fishers throughout the system. The catch is principally sold after retaining a small amount (~ 1 kg) for household consumption. The vendors collect fish from landing sites at the tanks and take fish to consumers around local villages. A cycle vendor and motorcycle vendor are shown in Plate 2.1. Murray *et al*. (2001) estimated that cycle vendors distribute 10-20 kg per day reaching even the most remote villages. Most fishers are tied to using the same cycle vendor by informal arrangements. At some tanks vendors offered fishers credit for net purchases or loaned nets to fishers in order to cement their relationship and secure future fish supplies. In times of seasonal gluts of fish it is not uncommon for a larger number of vendors to enter the occupation which is facilitated by the low entry costs. In tanks such as Rajangana wholesalers uplift fish with vans or motorcycles to distribute fish to other wholesalers or vendors further afield. In all sectors of the chain most fish is sold by midday indicating the high demand for fish. A representation of the fish distribution networks within the North Western Province (Murray *et al*. 2001) is presented in Appendix 3.

Plate 2.1 System H fish vendors : A motor cycle vendor collects tilapia at Usgala Siyambalangamuwa tank (left). A cycle vendor (right) holding a large rohu steak, Thambuttegama (courtesy of F. Murray)

Availability of fish within Mahaweli System H.

The ranking exercises provided an overview of the range of species available within each village. Availability of fish in all villages was found to be high. In fishing households in tank-based communities this was derived entirely from their own catch. Households in canal-based villages depended on vendors for their fish supply and are normally serviced by these vendors twice daily.

Consumer preference and demand for tilapia was high. Tilapia were the dominant species found within the catch and most available to consumers. In VIJ, KAT and KAL, a distinction between *Oreochromis mossambicus* and *Oreochromis niloticus* was made. This distinction was based on the colour of the fish with *Oreochromis mossambicus* called "black" tilapia and *Oreochromis niloticus* called "white" tilapia by respondents. Their market prices were between Rs. 25/kg for small tilapia (between 50-100g) Rs. 35 for medium tilapia (150-200g) and Rs. 40/kg. for large tilapia (> 250g). Other preferred species such as snakehead were less available in the catch, but preferred due to their relatively low bone content and good taste. Fishermen reported that snakehead were normally retained for home consumption rather than sold. It also emerged that the indigenous carp *Labeo dussumieri* was liked due to its good taste but was no longer available in the catch. Some respondents blamed the introduction of tilapia for its disappearance. The actual data derived from the consumer preference ranking exercises is presented in Table 2.5 to highlight the differences in the range of species available and village location. The greatest range and availability of species was identified at VIJ. Muslim respondents interviewed in VIJ were part of a long established fishing community and seemed to have greater knowledge of the range of different fish species in comparison to the respondents in other villages.

These findings indicate the overall extent to which tilapia is important in System H and its consistently high preference rank by the majority of respondents indicated high consumer acceptability and demand.

Only respondents at USG and KAT cited the availability of *Amblypharyngodon melettinus*, a small minor cyprinid, during the ranking exercises. In subsequent discussions this species was found to be available year-round in many tanks although it was mainly caught in the dry season when the abundant catches could be easily dried and retained for household consumption, sold to local shops or, in the case of RAJ village, sold on to middlemen for wider distribution.

Table 2.5 Summary ranks of consumer preference ranking in villages of Mahaweli System H, Sri Lanka.

	VIJ			MDG			DOM			KAT			KAL			USG			RAJ		
Fish species	G[1]1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3	G1	G2	G3
Oreochromis mossambicus	2	3	9	7						1	5		1	1	1	2	1	2	1	1	2
Oreochromis niloticus	1	4	7	2	1	2	1	2	1	2	1	1	1	1	1	2	1	2	1	1	1
Channa striata	8	1	8	4	2	1	2	3	2	3	9	2	2	2	2	3	4	1	2	2	3
Puntius ticto	3	9	2	6				6	8	4	11	5		4							
Cirrhinus mrigala	5	15	5							5						1	2		3	3	4
Belontia signata	9	8	3	9		3				6	2										
Mystus spp.		7							9	7		8									
Cyprinus carpio	4	14					3	5	6	8		4					3	4			
Etroplus suratensis	7	5	6	3	3			4	3	9		7	5				6	5	4		5
Etroplus maculatus										10											
Puntius filamentosis	6	6	1						5	11	12	6	4			5	7	7			
Anguilla bicolor	10	12						7	4		3										
Trichogaster pectoralis				8							4										
Mystus vittatus											7										
Mystus keletius											8										
Clarius brachysoma		16									10										
Mastacembelus armatus	13	13	4	5				1			13										
Heteropneustes fossilis	12	10							7		14										
Labeo dussimieri												3									
Channa marulius	11	2		1																	
Amblypharyngodon melettinus													3	3	3	4	5	6			

[1] G prefix refers to group. Three replicates of group interviews were undertaken in each location

2.4 Discussion

The appraisal identified key vulnerability characteristics in the livelihoods of both fishers and farmers. The main contributing factors to household vulnerability originate from seasonal fluctuations in income sources such as fishing and agriculture in addition to the underlying negative changes and trends affecting returns to investment and labour of these activities. The potential role of aquaculture within the prevailing livelihood context is discussed in this section.

2.4.1 Critique of the methodology

The process of the participatory situation appraisal led to the identification of a research focus which could reduce household vulnerability caused by seasonality amongst fishers and fisher-farmers. Methodologies need to be constantly reassessed and adapted to both understand current systems and develop innovative systems in participation with stakeholders which are relevant to a wider range of situations. The need for rapid assimilation of contextual information potentially meant that trade offs in accuracy or participation had to be made in some cases. However, the 'quick and dirty' rapid assimilation of information during the appraisal process served to identify an appropriate research focus which could meet the needs of the poor.

The initial selection of canal-based villages in preference to tank-based villages was adjusted in recognition of the importance of tanks within North Western Province. This was caused by an attempt to ask the same research question in a different context both in terms of hydrological and socio-economic conditions.

To a large extent the success of the exercise depended on the training and interpersonal skills of the facilitator.

As Sri Lankans even in rural areas have a high literacy level, some participatory methods for timelines such as those using sticks and drawing lines on the ground (Intercooperation, 1993) were abandoned as they were deemed patronising in the context. People were not used to drawing on the ground and more accustomed to attending meetings in purpose built areas such as the temple hall or other communal meeting place. When the timeline was conducted in a public group setting a more transient population was noted. Participants were reluctant to stand around and subsequently moved on to other activities. The seasonal timing of the appraisal conducted in November 1999 created problems as it was at a time of high agricultural activity for land preparation and planting of the *maha* season's paddy crop in many villages. This meant that people's time for participation was limited and the methods used for the appraisal had to be rapid for both the participants and the facilitators. When participants were offered the pen to write on the timeline they often refused feeling self-conscious about writing in public. To reduce the time required, the facilitator created a timeline on a large sheet of paper as a focus for discussion. The timeline methodology could have been improved as it shifted from being extremely participatory in that group members were encouraged to draw on the paper to being dominated by the facilitator.

2.4.2 Shocks and trends

The key shocks identified were droughts in the 1970s. This can only be ascertained from time-series analysis of drought events within Mahaweli System H area and consideration of the benefits of recent irrigation development and water management practice in offsetting the impact of water scarcity and drought on farmers and other water users such as fishers. However, aquaculture depends on water availability to succeed. Introducing aquaculture in a water scarce environment may increase household covariate risk[1] (Ellis, 2000) by adopting another water (principally rainfall) dependent livelihood activity. In other parts of Asia aquaculture is practiced where water is scarce and seasonal, such as rice-field based aquaculture in rainfed areas of South East Asia (Little *et al.*, 1996). This is, of course, context specific but may be feasible in areas where there is a constant demand for certain aquatic products, irrespective of size. An example of this may be fingerling supply to operators utilising perennial water bodies or paddy fields. Emergency harvests in times of water scarcity may not be feasible for food fish producers who may have 'undersized' and non-marketable products in this event. Therefore, for many types of aquaculture to be both technically and economically sound water supply needs to be reliable and predictable even if it is available for short periods. This highlights that water availability is not the only issue for consideration when determining whether aquaculture can be integrated within irrigation systems; reliability and predictability are also important. It is also important to note complementary linkages; synchronising fish production, water availability and the market.

[1] The factors that create risk for one stream of livelihood income (such as rainfall) are the same as those factor which create risk for other livelihood activities with which the household is involved. For example, a drought would result in failure of all income streams where the household income portfolio is generated from agriculture, fisheries and on-farm labour.

Livelihood activities

In all villages, with the exception of RAJ, livelihood strategies have changed in response to the decreasing returns achieved from farming. Farmers cited that the increasing input costs and low farm-gate prices for paddy made farming a far less reliable activity than it was 10-20 years ago. In USG, KAT and KAL, villages situated on tanks, fishing has emerged as a supplementary livelihood activity for farming households but is also undertaken as a full-time occupation by the landless or those with a fragmented landholding. Many women in these villages were reluctant to admit that their husbands were fishing to supplement household income. This was apparently due to the perception that fishing was both a low-caste activity, but also the domain of the "poorest of the poor". The low status of fishing is a general phenomenon also reported by Pauly (1997), Pollnac (1991), Christy Jn. (1986); Panayotou (1982) and Smith (1979).

Cultivation of rice now appears to be mainly undertaken to ensure household rice security rather than for profit. This indicated that agriculture, for paddy at least, is shifting towards a subsistence rather than profit-making enterprise as farmers increasingly depend on other income sources to meet household expenditure. This concurs with the findings of Tudor *et al.* (1999) who question the future economic viability of agriculture in Sri Lanka. Most households in villages where fisher-farmer livelihoods had emerged had diversified their income sources. This was likely to have been forced as a result of increasing input requirements and decreasing profitability of farming. Ellis (2000) describes the reasons for diversification being related to necessity or choice. It has also been described as survival or choice (Davies, 1996) or survival and accumulation (Hart, 1994).

Fisheries

The fishery in perennial tanks is dominated by tilapias. In tanks such as Kalankuttiya, Kalawewa and Kattiyawa catches were greatest in the dry season when the water-spread area is least and depth is minimal. When water spread area is large, fish stocks are more difficult to exploit and catch per unit effort (CPUE) subsequently declines. Findings of fisheries studies in Sri Lankan tanks by Brugere (2002) and Amarasinghe (1998) support this case. At USG and RAJ villages fishers gave a contradictory account of CPUE and seasonality in comparison to the other tanks visited during the appraisal. Variability in seasonality of CPUE could be a function of heterogeneity within the community and perhaps indicative of fishers' responsiveness to changing fishing conditions in that seasonal high and low catches are not as clearly demarcated as in other tanks where fishing is a smaller component of the household livelihood strategy. This, however, required further quantification between different tank fisheries as some degree of fishing seasonality was present in all villages and this contributes to the vulnerability of all households for whom reliance on the fishery plays an important role in livelihoods i.e. fisher-farming and fishing only strategies.

Migration

Fishers at Rajangana had migrated from the western coastal areas of Chilaw and Negombo where they had been in-shore artisanal fishers to form small-scale fishing communities around Rajangana tank. This adaptive strategy resulted from the development of marine fisheries and increasing competition from commercial vessels. As a result, many traditional fishermen in the coastal areas had to join trawler fleets paid on a wage basis. As this capped the fishers' earning capacity coastal fishing families migrated from the coast to exploit the inland fishery. It seems that both push and pull factors were behind their migration; pushed by the changing circumstances in the coastal fishery and pulled by the potential to tap into under exploited fishery resources inland. Despite their migration and settlement at Rajangana tank since 1962, many households maintained strong networks with relatives and friends in the coastal areas. This may be due in part to their cultural isolation from other Sinhalese Buddhist farming communities in the area; differing in their religion (Christianity) and their livelihood types (fishing). Allison & Ellis (2001) report similar circumstances in Lake Malawi where migrant fishers were often ethnically different from other villagers who were predominantly interested in farming rather than fishing. This may also contribute to socio-cultural as well as geographical isolation of migrant fishing communities around Rajangana tank and may ultimately increase their poverty through reduced access to information and services. In this community the maintenance of social connections with coastal fishing communities was important as they were drawn upon to find seasonal employment when fishing conditions inland are poor. Many rural households see social networks as an investment in maintenance of future livelihood security (Berry, 1993). The importance allocated to maintaining social networks is also reported in Africa and has been linked to increased income in villages in Tanzania (Narayan & Pritchett, 1999).

The increased popularity of overseas migration by young women highlights the importance of remittances in supporting livelihoods. Liberalisation of overseas travel and employment has facilitated this process (Gunethilleke, 2000) but it is equally likely that many women are pushed into migration by chronic poverty and erosion of assets (such as land) and pulled by the high earning differentials of employment overseas. However, migration of either long or short-term appears to be at some social cost; fathers and extended families left to manage childcare and household chores and sudden increases of wealth resented by other villagers.

2.4.3 Markets and consumer preferences

The market for tilapias in the research area is well established, highly organised and decentralised, providing excellent delivery of fresh, inexpensive fish to most rural households. The findings of the focus group interviews and consumer preference ranking confirm those of Murray *et al.* (2001) indicating that tilapia are preferred over all other fish species. Interviews with vendors indicated that demand exceeds supply, especially into the *maha* season when tilapias become more difficult to exploit in the larger perennial tanks. Preference ranking exercises with rural consumers and semi-structured interviews conducted at the same time confirmed that tilapia is consumed far more than any other animal protein source in rural areas. The relatively low price and high availability of tilapias compared to other animal protein sources were key factors determining overall preference for tilapia amongst consumers. The initial situation appraisal in the tanks studied indicated that variability in tilapia prices between seasons was low. Murray *et al*. (2001) indicate that prices vary, principally in response to changes in availability by a maximum of Rs. 10 / kg. Tilapias are priced according to size with smaller fish less than 250g fetching Rs. 20-25/kg and larger fish above 250g fetching Rs. 35-40/kg. Vendors reported that larger fish are often the first to sell and that strong, unfulfilled, demand for larger fish exists.

2.4.4 Implications for aquaculture

Livelihoods in all villages are vulnerable to a loss of income caused by long-term trends including decreasing profitability of farming, increasing dependence on remittance incomes, increasing out-migration of the most economically active groups i.e. young men and women and growing pressure on the inland fishery. Vulnerability caused by negative trends in farming and fishing is compounded by the effect of seasonality; both activities experiencing seasonal gluts of supply and the perishable nature of the produce (with the exception of paddy) forcing producers to sell at lower unit prices during these periods. This inability to smooth supply of goods to the marketplace and exploit periods of high demand and price is one aspect that contributes significantly to vulnerability of household incomes.

Consequently, two key strategies for reducing household vulnerability to low income were identified through the situation appraisal:

- Diversification of household income generation away from agriculture and fisheries dependent activities

- Smoothing supply of produce to market by out of season cropping (for agriculture) or controlling release of produce to the market place.

The emergence of migration and off-farm employment indicates that the first strategy is already being undertaken to meet both household income requirements whilst achieving an ancillary objective of reducing vulnerability to loss of income from the failure of either agriculture or fisheries. Controlling the supply of fish to market to exploit periods of peak demand is one function which aquaculture could fulfil. High consumer demand and seasonal variability in supply of large tilapia reinforce its viability. The increase in price of tilapia over 250g suggests that in particular, supplying larger tilapia may be the most lucrative niche for aquaculture to fill.

2.5 Site selection and appropriate technical options

In the context of the North Western Province obvious technical opportunities exist to culture fish in cages/pens within the perennial irrigation tanks. Although the technical knowledge of aquaculture systems in canals was limited and has lacked explicit poverty focus (Chapter 1), canals within Mahaweli System H and had little potential for aquaculture due to steep banks impeding canal access, high water velocity and sporadic water supply. Aquaculture potential in canals was eliminated at this stage due to these access and supply constraints. Therefore villages located on the Right Bank Main canal (VIJ, MDG and DOM) were excluded from further study. Tanks with their perennial water supply and relative environmental stability were deemed conducive physical environments for aquaculture intervention and from this point, cage and pen aquaculture were given most consideration. Within the tank-based communities surveyed the village at Kalankuttiya tank (KAL village) was excluded due to the fact that the tank was dry at the time of survey and that the local fishing society was disbanded due to financial irregularities. KAT village was considered an option for intervention, although logistical issues constrained the ability to work closely with participants in this community. Therefore RAJ and USG villages were selected for the study due to their ease of access, as further technical interventions would require much greater contact with participants.

Farmers in communities surrounding tanks were becoming increasingly vulnerable due to the reduced returns from agriculture and had begun to diversify their income sources through participation in fishing. Fishing dependent livelihood also experienced vulnerability though the decreasing catches over time and seasonal variation in incomes from fishing. Communities that exhibited these characteristics were preliminarily selected for aquaculture interventions. In this context, the villages of USG and RAJ were selected as having the greatest potential to deliver direct livelihood benefits through aquaculture and had a compatible perennial water resource with which to do so.

Having established the nature of vulnerability and the consumer demand for fish a potential niche for aquaculture to meet the shortfall in large tilapia availability was identified as a possible research focus. Chapter 3 outlines the possible resources and technical options which were identified as having a potential role in our objective to develop a poverty-focused research agenda.

Chapter 3 Resource Assessment for Aquaculture

The previous chapter highlighted key livelihood issues and the marketing potentials for tilapia aquaculture. A key consideration is how tilapia culture could play a role in alleviating poverty through reducing livelihood vulnerability of households who, to varying degrees, depend on fishing for their livelihood. The appraisal also highlighted the issue that negative trends in agriculture and fisheries are compounded by seasonality. Hence a need for an alternative or supplementary income generating activity was identified. A key feature of seasonality for fishers is the variable catches noted in both system and non-system tanks. Fishing also seemed to exhibit greater variability amongst fishers in 'non-system' tanks and merited further investigation to ascertain the reasons for this characteristic. Marketing and consumer preference studies indicated that tilapia was the most favoured species of fish within all the communities studied in the Mahaweli System H area. For these reasons tilapia aquaculture was deemed a potential research focus. The previous chapter, therefore, served to determine *if* there was a role for aquaculture given prevailing livelihood and marketing backdrop in Mahaweli System H. This chapter goes on to consider *how* people in tank-based communities could undertake aquaculture and explore to more explicitly the resource and economic issues that complement the case for aquaculture put forward in the initial situation appraisal.

3.1 Introduction

Prior to conducting any resource assessment for aquaculture the nature of the system (water body and production type) and biological requirements of the species must be evaluated through a resource assessment. Once these aspects have been established availability and seasonality of water supply, feeds, seed and construction materials must be evaluated. A trade-off had to be made between selected systems that may work technically and maintaining poverty-focus by being both low cost and accessible to the poorest user groups. It was hoped that participants could be offered a "basket of choices" rather than predetermined technology packages with the researcher taking on the role of "catalyst, intermediary, facilitator, searcher and supplier" (Chambers, 1993). The challenge was to identify potential approaches for integration of aquaculture within the irrigation systems particularly given a context of high production levels and availability of tilapia from perennial tank fisheries. Tilapias have favourable characteristics; hardiness, ease of culture and wide ranging food preferences (Jauncey, 1998), and, in the context of Mahaweli H, high market acceptability. However, this did not necessarily mean that aquaculture could be viable. For tilapia aquaculture to be an attractive and viable, given its low price, production costs would need to be low. Potentially this could favour the poor if initial investment costs and associated risks were low.

The following chapter charts the process of evaluating the potential for tilapia aquaculture for integration within existing irrigation structures, the decision-making process of identifying the type of system most appropriate to maintain a poverty-focus and the assessment of resources with potential use in aquaculture.

3.2 Background

The identification of suitable aquaculture inputs and development of low cost systems is crucial if aquaculture with an explicit poverty-focus for producers is to be viable in this context. Current research into the potential for on-farm production of fish-meal based feeds has been undertaken (Amarasinghe *et al*. 2002). This aspect received attention due to research indicating that minor cyprinids such as *A. melettinus*, for use in fishmeal production have the potential to be exploited using small meshes without detriment to other species (Sirisena & De Silva, 1989; De Silva & Sirisena, 1987) although Fernando (1999) disputes these findings.

As fisheries will continue to meet most of the supply for fish in the rural areas of North Western Province for the foreseeable future, opportunities for aquaculture are limited. However, seasonal fluctuations in the availability of tilapia coupled with high consumer demand for large tilapia signify a potentially untapped niche for aquaculture. Appropriate timing of marketing may provide aquaculture producers with a market advantage and vendors and consumers may even pay a premium for larger fish during the lean period, which may favour the economic viability of aquaculture.

3.2.1 The potential for cage aquaculture

The technical feasibility of many tilapia aquaculture systems has been proven and widely adopted in many countries. Pond culture, the most common approach elsewhere in Asia, was excluded as a potential technical research option for two main reasons (i) ponds do not form part of a large scale irrigation system and (ii) landlessness and high value attached to land for paddy cultivation rendered land-based aquaculture systems unsuitable. Cages in canals were also excluded on the basis that water availability was sporadic and canal access was poor in some areas. The large perennial tanks in the North Western Province therefore presented the greatest opportunities for aquaculture, as ownership of land was not a pre-requisite. This provided a good poverty focus as landless or land poor groups can access the resource. Pens and cages have been used extensively in perennial reservoirs and lakes in other parts of Asia (Costa-Pierce & Hadikusumah, 1990; (Rusydi & Lampe, 1990; Costa-Pierce *et al* 1990; Tantikitti & Rittibhonbhun, 1988). The main constraint to pen aquaculture, however, was the unit cost of producing a large pen and the fixed structure of a pen were not adaptable to seasonal fluctuations in tank water levels.

Cages presented a more appealing technical solution. Cages have several benefits for the poorest groups when compared with other culture systems. Principally, cages are not dependent on land, which is a pre-requisite for pond-based aquaculture, therefore landless or land-poor people can potentially undertake cage culture. They can also be made in small units at a lower cost and they can be highly stocked as an intensive culture system thereby maximising or optimising production per unit volume. Experiences of the CARE CAGES project in Bangladesh have demonstrated that small, inexpensive, cages are also manoeuvrable and can be easily managed to facilitate access and harvesting (Kabir & Huque, 2000). In particular floating cages can be fabricated to accommodate water level fluctuations, which would reduce the need to relocate cages in response to such a situation.

For these reasons cage aquaculture was deemed to have the most potential as a culture system. It was hypothesised that small cage units located near the shore line would reduce risks and that even poor households would be able to access and manage them. Thus a focus of cage culture as a low-cost, poverty-focused aquaculture system was needed. Before discussing the system with potential participants it was decided that a resource assessment was needed to evaluate resources. The potential for small, undersized, tilapia to be caught live and ‘fattened’ to a marketable size over 250g (the threshold identified by fishers and vendors where tilapia qualify as ‘large’) became the central technical focus. Catching tilapia from the fishery, holding and fattening them to a marketable size was not identified within the existing literature for tilapia in Asia, although Edwards (2004) reports that South East Asian fishers used cages to hold the catch prior to marketing. Cage-based fattening of lobsters using local trash fish species has been reported as an activity undertaken by fishers in response to a higher market price for larger lobster in Vietnam (Bulcock *et al*. 2000). Cage-based fattening of tilapia from the wild fishery was selected as a research focus, contributing a poverty-focused dimension to aquaculture research in Sri Lanka.

Farmer-made feeds

A key input for cage aquaculture is the availability of prepared feed. This is necessary as fish are denied access to their natural feeding environment as they are suspended in a cage. Although tilapia have many feeding modes, utilising zooplankton, phytoplankton and macrophytes (Beveridge and Baird, 2000) and can graze on periphyton in cages (Huchette and Beveridge, 2005), fish are largely denied access to their natural feeding environment whilst in cages. Jauncey (1998) states that even in apparently intensive culture, tilapias are well adapted to using even minimal amounts of natural feed. However, as there was no means of determining the proportion of feed gained from natural sources and that accounted for by a prepared diet, development of a farmer-made feed was necessary to ensure caged fish received sufficient feed to grow. To reduce entry costs for potential producers and because formulated feeds for the aquaculture sector were not widely available, the concept of preparing an on-farm (farmer-made) feed using local ingredients was explored.

Most Asian aquaculture occurs in semi-intensive pond farming systems, depending on fertilisers or farmer-made feeds (New *et al*. 1993). The bulk of ingredients used in these feeds consist of agricultural by-products and by-products of the animal husbandry industry (De Silva, 1993). As the costs of aquaculture feeds will reflect the severity of competition and availability of conventional feedstuffs in each country (New and Csavas, 1993), situations where feed availability does not conflict with agriculture or other competing uses are highly desirable. A resource assessment was vital to determine any competing uses of feedstuffs.

3.3 Methodology

The main focus of the resource assessment was to triangulate information about water resource availability and prevalence of small tilapia in the catch. The focus on cage aquaculture meant that the availability of potential cage materials and feed resources were significant inputs which required definition in terms of their spatial and temporal availability and cost.

To assess water depth in the tanks and assess potential sites for cages the depth of some areas of USG tank was measured using a plumb line for broad guidance prior to any further intervention.

The resource assessment was conducted by holding semi-structured interviews with fishers, local retailers, rice millers and animal (principally poultry) feed outlets. Seasonal calendars were used to plot variation in resource availability. A checklist table was used to interview suppliers for itemising and pricing resources with potential use in aquaculture. This assessment sought to establish potential cage materials, feed resources and to determine the availability of small tilapia for stocking in cages. Availability of small tilapia in USG and RAJ villages is presented in relative terms with 1 = low availability, 2 = moderate availability and 3 = high availability. Any seasonal dimension to the availability of all inputs was considered and recorded.

Further to this, an economic sensitivity analysis was designed drawing on the work of Shang (1982), Little & Muir (1987) and Christensen (1989) to determine the likelihood of economic viability based on cage designs fabricated from local materials and using farmer-made feed. Cage designs were based on the materials identified during the resource assessment. Feed formulation and inherent costs were also calculated on the basis of the results of the assessment. The details of each case scenario are included as a footnote to the economic analysis results. Assumed food conversion ratios (FCRs) calculated as Wet Weight Fed (kg) /Wet Fish Weight (kg) were used to determine potential profitability under varying conditions.

3.4 Results

3.4.1 Water availability

Water was perennially available within the tank irrigation system so this was not viewed as a constraint. However, the tanks increase in volume in accordance with monsoon rainfall and decrease in volume according to evapotranspiration losses and irrigation water issues. The situation appraisal therefore sought to interview farmers about the nature of water supply to the tanks in the study villages. System tanks such as Kalankuttiya, Kattiyawa and Kalawewa store and release water from via a network of canals. At the time of survey, Kalankuttiya tank was dry due to the construction of a feeder canal to regulate water flow and water was released into the canals in the subsequent year. In Kalankuttiya, Kattiyawa and Kalawewa tanks the inflow and outflow patterns tended not to follow rainfall patterns as closely as Usgala and Rajangana tanks whose principal input is rainfall, rather than from upstream tanks fed by a connecting canal. Rajangana tank receives drainage water and increased in volume in the *maha* season both from rainfall input and drainage from the fields irrigated by Mahaweli system H. As tank water levels vary, so does the tank's water spread area. All tanks have variable water spread areas, although the volumes of tanks such as Kalankuttiya can decrease in volume rapidly if water is issued to downstream tanks. Both Usgala and Rajangana tanks have slow and steady water level variations following a seasonal pattern of accumulation from November when *maha* rains begin and receding from around April onwards as the *yala* seasonal commences.

3.4.2 Cage materials

Floating rather than fixed cages were envisaged as having greatest relevance given the variations in water levels experienced in tanks. With the exception of government-led interventions cage and pen aquaculture is undeveloped in Sri Lanka. This meant that the availability of materials suitable for small-scale cage aquaculture within the local area was restricted. Most net materials used for cage and floating hapa construction in the government interventions were expensive and imported from India by CEYNOR (a joint venture between the Sri Lankan Department of Fisheries and NORAD, the Norwegian development assistance bureau) which would significantly increase entry costs to poorer user groups. The notion of importing net materials was dismissed in favour of locating low cost materials that could be used to some effect for cage construction. A full inventory of cage materials identified is listed in Appendix 4 with their relative availability and cost indicated. Key cage materials are summarised in Table 3.1. Woods such as *ipil ipil* (*Leucaena leucocephala*) and bamboo were widely available in the areas surveyed. Other materials such as iron bars and nylon net meshes that could be used to make cages were also commonly used within the communities.

No conventional cage materials such as HDPE (High Density Polyethylene) netting or other HDPE polymer nettings such as Netlon™ were available and needed to be imported through CEYNOR as stated above. Of major importance however, was the availability of local fishing net materials and low cost of local bamboo.

Table 3.1 Availability and cost of potential cage materials in Galgamuwa town

	Material	Availability and location	Local Unit Price (Rs.)
	Bamboo culms	High	Rs 1 / ft
	P.V.C. Pipe (20mm diameter)	High and local	Rs. 85 / 13ft length
Frame	P.V.C. Pipe (32mm diameter)	High and local	Rs. 153.50 / 13ft length
	P.V.C. joints	High and local	Rs. 12 – Rs. 22.50
	Iron bar (1.0 cm diameter) - plain	High and local	Rs. 75 / 18ft
	Iron bar (1.0 cm diameter) - twist	High and local	Rs. 135 / 18ft
	Iron bar twist (1.2cm diameter)	High and local	Rs 105 / 18ft
	Iron bar (1.6cm diameter)	High and local	Rs. 210 / 18ft.
Mesh	Chicken wire 22 gauge	High and local	Rs. 54 / m^2
	Nylon fishing nets (various sizes)	High and local	> Rs. 2400 / net
	Plastic water cans (20 litres)	High and local	Rs. 100
Floatation	Plastic water cans (35 litres)	High and local	Rs. 150
	Polystyrene blocks	High and local	Rs. 65
	Sandbags	High and local	Rs. 7-10
Anchorage	Rice sacks	High and local	Rs. 5
	Large stone	Moderate and local	Free
	Coir rope (1.5 cm diameter)	High and local	Rs. 45/kg
Miscellaneous	HDPE rope	High and local	Rs 45/kg
	Padlock	High and local	Rs. 165 - 265

1 US $ = 83 Sri Lankan Rupees (Source - http://www.oanda.com/convert/fxhistory/ Time period = 01/01/00 to 01/07/02.)

3.4.3 Feed

The tank fisheries are noted for the concentration of small freshwater cyprinids such as *Amblypharyngodon melettinus*, *Rasbora daniconus* and *Puntius spp* (Sirisena & De Silva, 1989; De Silva & Sirisena, 1987). Although these species were not reported during the focus group interviews or consumer preferences ranking exercises, subsequent key informant interviews revealed that these fish were abundant in the tank fishery and were caught using a small 23 mm mesh and were mainly targeted during the dry season. Once landed they were either sold fresh or after drying in home gardens. Their market value when caught fresh from the tank was Rs. 15 per kg. Production of 1 kg of dried fish takes 3 kg of fresh fish using salt for preservation. However, the market value of dried fish was Rs. 40/kg. and when the cost of the salt was taken into account, it became apparent that this activity performed a salvage rather than value addition function. This activity also suggested a limited market for fresh minor cyprinids. This was confirmed in discussion with fish vendors who stated that minor cyprinids and were more difficult to sell in large quantities as they were perishable and demand was not sufficiently high to ensure sale before spoiling. Any unsold fish were taken home by vendors the vendors and dried. Furthermore, at RAJ, another species (*G. guiris*) with potential use in a farmer-made feed was identified. This species was found to have little or no economic value and was usually discarded from the catch.

The abundance of small minor cyprinids and other fish species identified and their low opportunity cost suggested their potential use as an ingredient in a farmer-made feed. The preparation of fishmeal by the fisher household was constrained by a lack of facilities in either village for drying fish sufficiently to be ground into meal. Local key informants deemed sun-drying alone ineffective as a means of desiccating fish to a stage where they could easily be ground to a powdered form.

The use of fresh fish in feed preparation was addressed. Three main considerations were 1) It would take more fresh fish to give a similar dry matter protein value to conventional pelleted feeds used to rear tilapia 2) Feed stability in water may be poor if a very moist feed is delivered to a small area such as a $1m^3$ cage and 3) the potential for uneaten food to contribute to deteriorating water quality.

A survey of rice polish and rice bran availability in both USG and RAJ revealed some supply seasonality. Seasonal variations in availability are shown in Figure 3.1 and Figure 3.2. In both villages the relative availability of rice bran or polish is linked to the agricultural seasons, increasing after paddy is harvested as demand for rice milling increases substantially.

Rice polish was not available at USG village. The rice bran available within USG was produced from a metal rather than rubber belt milling process. Although the resultant rice bran was poor quality and contained approximately 50% husk, this could be improved by sieving to remove the residual husk. Its low cost (Rs. 0.5/kg, unsieved) made this a low-cost ingredient and very cheap. In RAJ both rice bran and rice polish were available for Rs. 2.5/kg and Rs. 5 respectively. Respondents in both communities reported that although production varied seasonally, availability was not a constraint. Farmers in USG also indicated that rice milling was undertaken whenever the household required more rice for consumption. In some cases, the rice millers in USG gave rice bran free of charge to repeat customers. As livestock rearing is relatively undeveloped in rural Sri Lanka (Chapter 1) competition for rice bran or polish in these communities was seemingly low. This may explain why rice bran has such a low economic value at the present time.

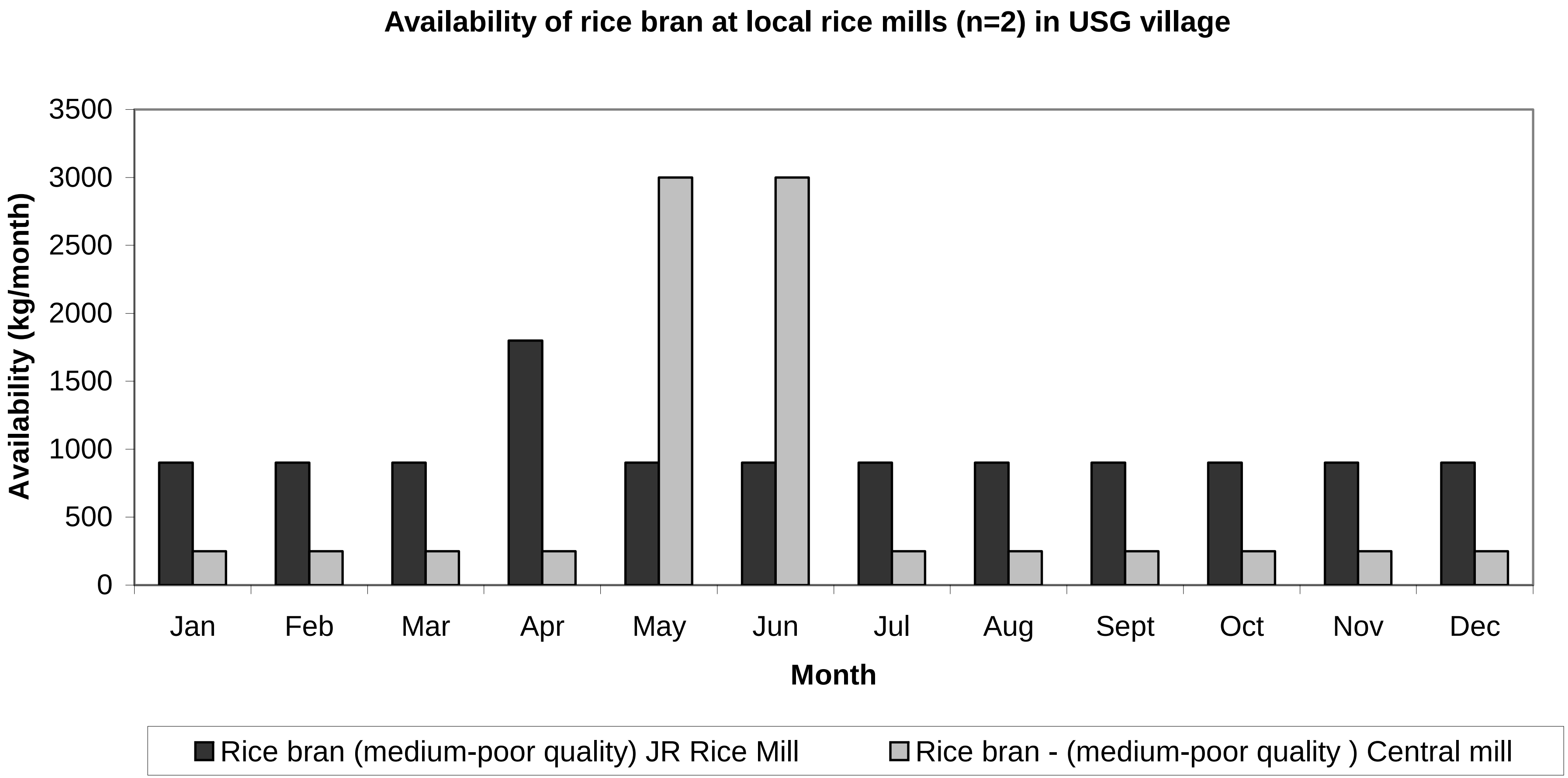

Figure 3.1 Seasonal availability of rice bran at USG village

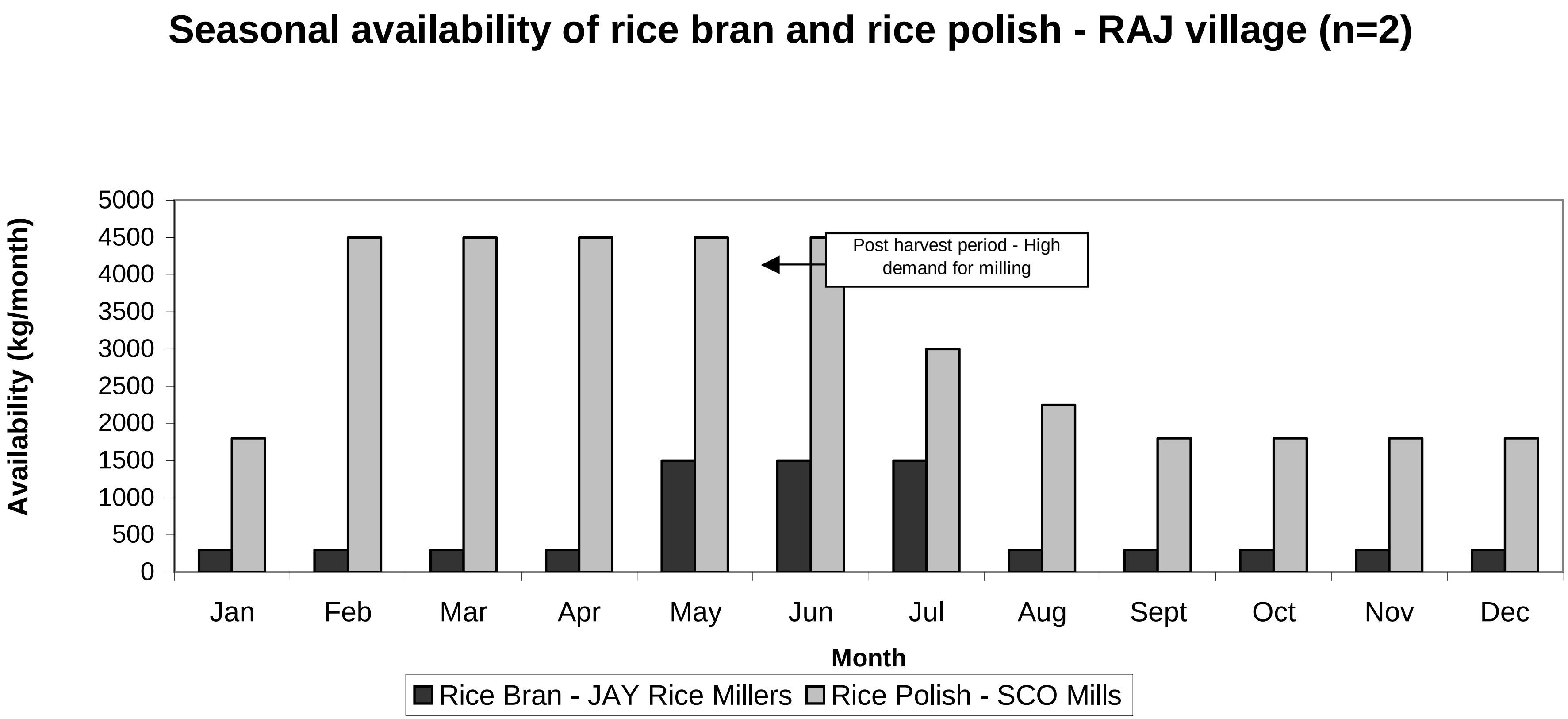

Figure 3.2 Seasonal availability of rice bran and rice polish at RAJ village

A summary of the identified feed constituents and their location is presented in Table 3.2.

Table 3.2 Potential feed ingredients available in USG and RAJ villages

Resource	USG	RAJ
Rice bran or rice polish	2 local rice mills Rice bran available at Rs. 0.5/kg	2 rice mills at Sirimapura junction and main road to Thambuttegama Rice bran available @ Rs. 2.5/kg Rice polish available @ Rs. 5/kg
"Trash" or low economic value fish species	*A. melettinus* *R. daniconus* *P. filamentosis*	*A. melettinus* *P. filamentosis* *G. guiris*
Seasonal availability of "trash" fish	Year round, although increased in dry season	

The availability of oilcakes as a by-product of oil pressing was low within the area and supply infrequent. Coconut production was concentrated in areas of Sri Lanka south of Kurunegala and therefore little coconut oil production took place in the North Western Province. Low livestock production in the province and little consequent demand for animal feeds such as oilcakes was also a contributing factor to low availability.

Poultry feeds were located in Thambuttegama and to a lesser extent in Galgamuwa. The types of feed available in these stores and their relative prices are presented in Table 3.3.

Table 3.3 Availability and price of poultry feed in the study area

Location	Manufacturer	Feed Type	Availability	Crude protein (% dry matter basis)	Price (Rs./kg)
Galgamuwa	Nutrena™	Broiler starter feed (containing antibiotics)	Year round 50 kg bags	24	30.8
Thambuttegama	Nutrena ™	Broiler starter feed (containing antibiotics)	Year round 50 kg bags	22	32.3
Thambuttegama	Gold Coin™	Broiler finisher feed	Year round 50 kg bags	19	30.8

Given the high price of poultry feeds and the limited availability of other livestock feeds the potential to produce farmer-made aquafeeds using small, low value, fishes as a source of protein and sieved rice bran was identified as the best low cost feed option.

3.4.4 Fish seed

Fish seed availability was investigated to assess the range of species available and their consistency of supply. Several factors were considered. Firstly, as the project was poverty focused and should ensure relevance of aquaculture to the needs of the poor the input costs should be kept low. Purchasing hatchery-produced fish seed would increase production cost and, in a market climate dominated by cheap fish, would adversely affect the economic viability of aquaculture. The marketability and overriding consumer preference for tilapia were the guiding factors which directed the resource assessment towards tilapia aquaculture. Therefore investigation of hatchery-produced carp seed was not pursued. Government carp and tilapia (*O. niloticus*) hatcheries were operational at Anuradhapura and Dambulla fisheries stations although pond producers found the consistency of supply erratic, seed quality problematic and hatchery production levels low. The study focused on assessing the availability of small tilapia, caught *in situ* to fatten to a marketable larger size.

Fishermen were interviewed about the seasonal catch of small tilapia in both USG and RAJ and seasonal variability depicted in for each tank respectively in Figure 3.3 and Figure 3.4. Relative availability was determined; 1= low, 2= medium and 3= high availability.

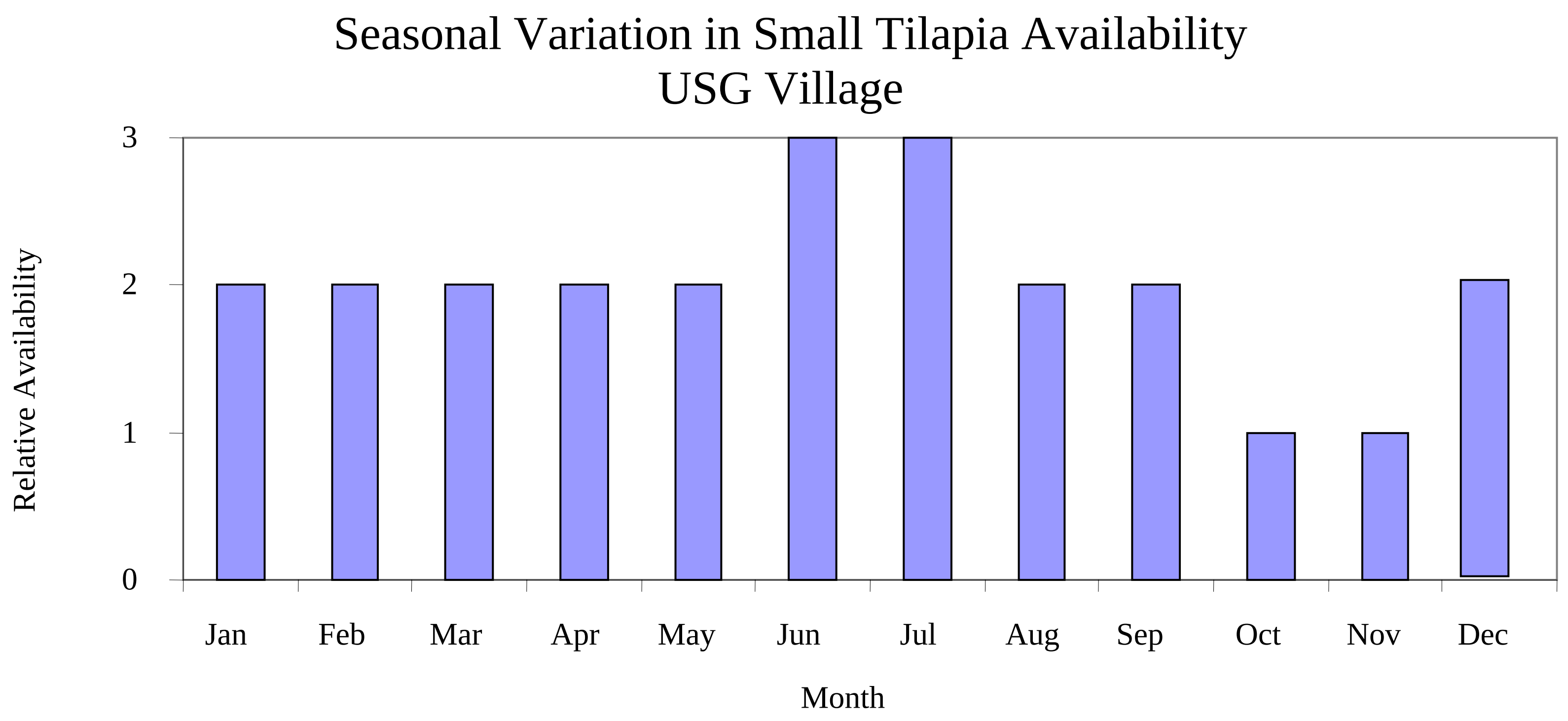

Figure 3.3 Seasonality of small tilapia (weight < 100g) catch at USG village

In USG village, the availability of small tilapia increased during the months of July and August. Fishermen reported that they preferred to catch large tilapia due to their higher market value but were forced to catch small tilapia at this time of year as catches of large fish decline. October and November are the period of the lowest catch of small tilapia, as larger fish are caught at this time at the onset of the *maha* monsoon rains.

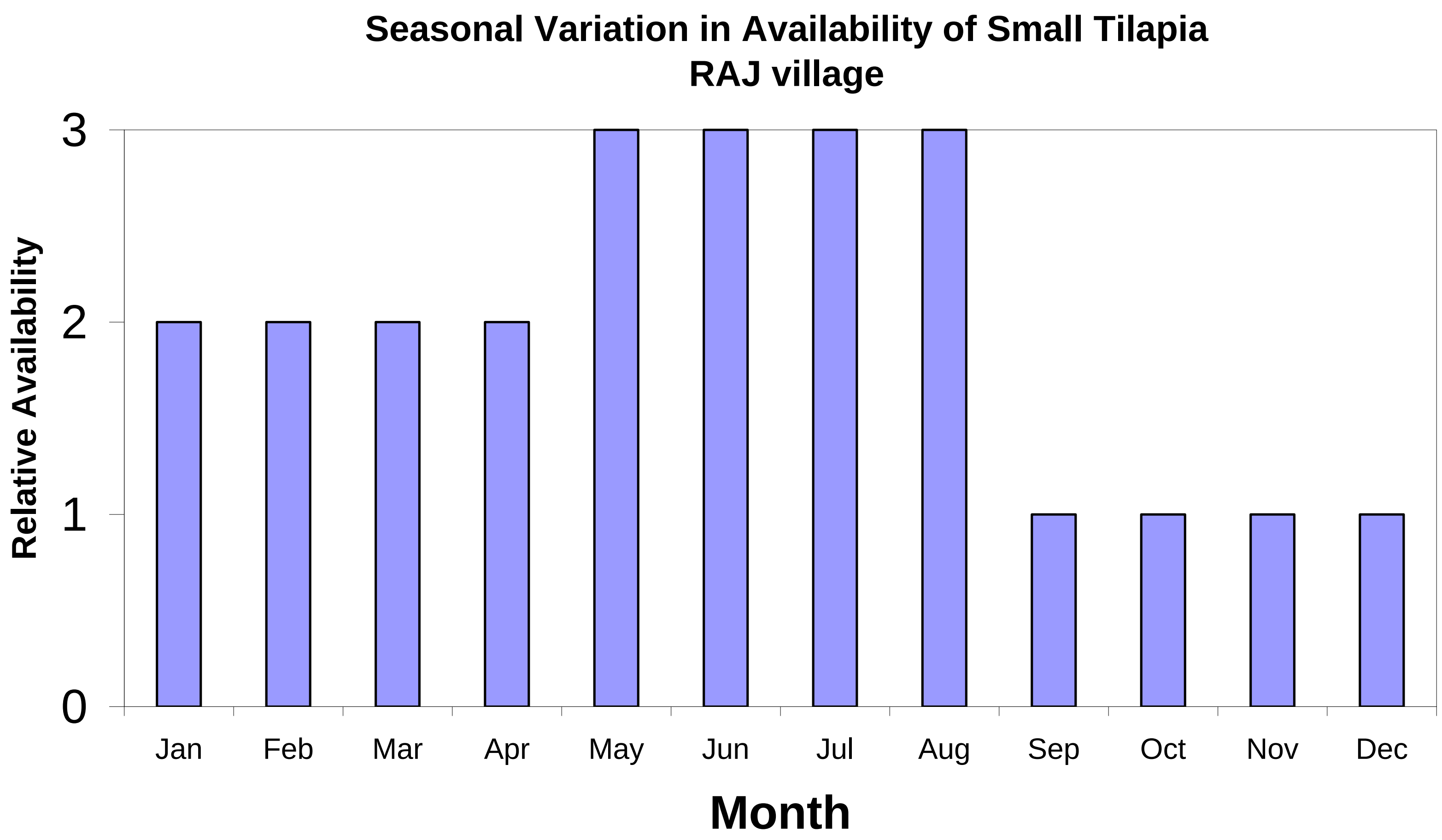

Figure 3.4 Seasonality of small tilapia (weight < 100g) catch at RAJ village

At RAJ village the catch of small tilapia followed a similar pattern. Catches increased from May to August. From September to December the catch of small tilapia decreased as medium and large fish dominated the catch at the onset of the *maha* rains. January to April was an intermediate period where any size of fish was caught. Many fishers reported that they reverted to catching small tilapia as large tilapia could no longer be caught after January.

The supply of small tilapia did exhibit some seasonality decreasing when large fish were available and preferentially caught by fishers in both USG and RAJ villages.

3.4.5 Sensitivity Analyses

The sensitivity analyses for two pre-selected cage designs (bamboo and metal mesh) are presented in Table 3.4 and Table 3.5. Key assumptions are noted below each table. Highlighted areas indicate profitable scenarios.

Table 3.4 Sensitivity analysis of cage-based fattening of tilapia using bamboo frame and net mesh bag cage design[1,2]

Weight at stocking (g)	Cage cost (Rs.)	Assumed cage lifespan (days)	Assumed FCR	Duration of culture cycle (days)	No. of culture cycles during working life of cage	Cage costs per culture cycle (Rs.)	Feed cost (Rs./kg)	Sieved feed cost (Rs./cycle)	Assumed stocking density/m3	Opportunity cost of seed (Rs.)	Total costs (Rs.)	Total benefits, 100% survival (Rs./cycle)	Net benefits, 100% survival (Rs./cycle)	Revised benefits, 20% mortality (Rs./cycle)	Revised net benefits, 20% mortality (Rs./cycle)	Payback periods for cage (cycles)	Payback period for cage with 20% mortalities (cycles)
50	1305.68	365	10	538	0.68	1924.54	8	3208.59	200	250	5383.14	2000	-3383.14	1600	-3783.14	-0.39	-0.35
75	1305.68	365	10	403	0.91	1441.62	8	2800.89	200	375	4617.51	2000	-2617.51	1600	-3017.51	-0.50	-0.43
100	1305.68	365	10	306	1.19	1094.63	8	2401.34	200	500	3995.97	2000	-1995.97	1600	-2395.97	-0.65	-0.54
125	1305.68	365	10	232	1.57	829.91	8	2007.25	200	625	3462.16	2000	-1462.16	1600	-1862.16	-0.89	-0.70
150	1305.68	365	10	171	2.13	611.70	8	1605.63	200	750	2967.33	2000	-967.33	1600	-1367.33	-1.35	-0.95
50	1305.68	365	5	270	1.35	965.85	8	1611.48	200	250	2827.32	2000	-827.32	1600	-1227.32	-1.58	-1.06
75	1305.68	365	5	202	1.81	722.60	8	1408.83	200	375	2506.43	2000	-506.43	1600	-906.43	-2.58	-1.44
50	1305.68	365	4	216	1.69	772.68	8	1287.24	200	250	2309.92	2000	-309.92	1600	-709.92	-4.21	-1.84
100	1305.68	365	5	154	2.37	550.89	8	1209.92	200	500	2260.81	2000	-260.81	1600	-660.81	-5.01	-1.98
75	1305.68	365	4	162	2.25	579.51	8	1130.42	200	375	2084.93	2000	-84.93	1600	-484.93	-15.37	-2.69
200	1305.68	365	10	75	4.87	268.29	8	806.08	200	1000	2074.37	2000	-74.37	1600	-474.37	-17.56	-2.75
125	1305.68	365	5	116	3.15	414.96	8	1001.55	200	625	2041.50	2000	-41.50	1600	-441.50	-31.46	-2.96
100	1305.68	365	4	123	2.97	440.00	8	964.43	200	500	1904.43	2000	95.57	1600	-304.43	13.66	-4.29
150	1305.68	365	5	86	4.24	307.64	8	807.28	200	750	1864.92	2000	135.08	1600	-264.92	9.67	-4.93
50	1305.68	365	3	163	2.24	583.09	8	963.02	200	250	1796.11	2000	203.89	1600	-196.11	6.40	-6.66
125	1305.68	365	4	93	3.92	332.68	8	802.80	200	625	1760.48	2000	239.52	1600	-160.48	5.45	-8.14
75	1305.68	365	3	122	2.99	436.42	8	840.02	200	375	1651.44	2000	348.56	1600	-51.44	3.75	-25.38
150	1305.68	365	4	69	5.29	246.83	8	647.61	200	750	1644.44	2000	355.56	1600	-44.44	3.67	-29.38
100	1305.68	365	3	94	3.88	336.26	8	730.96	200	500	1567.22	2000	432.78	1600	32.78	3.02	39.83
200	1305.68	365	5	39	9.36	139.51	8	408.37	200	1000	1547.88	2000	452.12	1600	52.12	2.89	25.05
125	1305.68	365	3	71	5.14	253.98	8	604.06	200	625	1483.04	2000	516.96	1600	116.96	2.53	11.16
200	1305.68	365	4	30	12.17	107.32	8	321.63	200	1000	1428.94	2000	571.06	1600	171.06	2.29	7.63
150	1305.68	365	3	53	6.89	189.59	8	487.94	200	750	1427.53	2000	572.47	1600	172.47	2.28	7.57
200	1305.68	365	3	23	15.87	82.28	8	246.88	200	1000	1329.15	2000	670.85	1600	270.85	1.95	4.82
50	1305.68	365	2	109	3.35	389.92	8	650.81	200	250	1290.73	2000	709.27	1600	309.27	1.84	4.22
75	1305.68	365	2	81	4.51	289.75	8	561.61	200	375	1226.36	2000	773.64	1600	373.64	1.69	3.49
100	1305.68	365	2	62	5.89	221.79	8	485.46	200	500	1207.25	2000	792.75	1600	392.75	1.65	3.32
150	1305.68	365	2	36	10.14	128.78	8	328.26	200	750	1207.04	2000	792.96	1600	392.96	1.65	3.32
125	1305.68	365	2	47	7.77	168.13	8	405.31	200	625	1198.44	2000	801.56	1600	401.56	1.63	3.25
200	1305.68	365	2	15	24.33	53.66	8	130.91	200	1000	1184.57	2000	815.43	1600	415.43	1.60	3.14

[1] Cage costs calculated on the basis that bamboo frame has a working life of 4 months and is replaced 3 times per year. Net mesh bag assumed to last 365 days.

[2] Opportunity costs of stocking fish are calculated based on fish weight on stocking and a market value of Rs. 25/kg. for small fish. Total benefits calculated at values of Rs. 40/kg for larger tilapia. Assumed food conversion ratios are given. Feed costs account for 50% waste husk sieved out prior to feed formulation.

Table 3.5. Sensitivity analysis of cage-based fattening of tilapia using galvanised metal mesh cage design[1]

Weight at stocking (g)	Cage cost (Rs.)	Assumed cage lifespan (days)	Assumed FCR	Duration of culture cycle (days)	No. of culture cycles during working life of cage	Cage costs per culture cycle (Rs.)	Feed cost (Rs./kg)	Sieved feed cost (Rs./cycle)	Assumed stocking density/m3	Opportunity cost of seed (Rs.)	Total costs (Rs.)	Total benefits, 100% survival (Rs./cycle)	Net benefits, 100% survival (Rs./cycle)	Revised benefits, 20% mortality (Rs./cycle)	Revised net benefits, 20% mortality (Rs./cycle)	Payback periods for cage (cycles)	Payback period for cage with 20% mortalities (cycles)
50	1585.75	365	10	538	0.68	2337.35	8	3208.59	200	250	5795.94	2000	-3795.94	1600	-4195.94	-0.42	-0.38
75	1585.75	365	10	403	0.91	1750.84	8	2800.89	200	375	4926.73	2000	-2926.73	1600	-3326.73	-0.54	-0.48
100	1585.75	365	10	306	1.19	1329.42	8	2401.34	200	500	4230.76	2000	-2230.76	1600	-2630.76	-0.71	-0.60
125	1585.75	365	10	232	1.57	1007.93	8	2007.25	200	625	3640.18	2000	-1640.18	1600	-2040.18	-0.97	-0.78
150	1585.75	365	10	171	2.13	742.91	8	1605.63	200	750	3098.54	2000	-1098.54	1600	-1498.54	-1.44	-1.06
50	1585.75	365	5	270	1.35	1173.02	8	1611.48	200	250	3034.50	2000	-1034.50	1600	-1434.50	-1.53	-1.11
75	1585.75	365	5	202	1.81	877.59	8	1408.83	200	375	2661.42	2000	-661.42	1600	-1061.42	-2.40	-1.49
[illegible]	1585.75	365	4	216	1.69	938.42	8	1287.24	200	250	2475.66	2000	-475.66	1600	-875.66	-3.33	-1.81
[illegible]	1585.75	365	5	154	2.37	669.06	8	1209.92	200	500	2378.98	2000	-378.98	1600	-778.98	-4.18	-2.04
[illegible]	1585.75	365	4	162	2.25	703.81	8	1130.42	200	375	2209.24	2000	-209.24	1600	-609.24	-7.58	-2.60
200	1585.75	365	10	75	4.87	325.84	8	806.08	200	1000	2131.92	2000	-131.92	1600	-531.92	-12.02	-2.98
125	1585.75	365	5	116	3.15	503.96	8	1001.55	200	625	2130.51	2000	-130.51	1600	-530.51	-12.15	-2.99
100	1585.75	365	4	123	2.97	534.38	8	964.43	200	500	1998.81	2000	1.19	1600	-398.81	1332.01	-3.98
150	1585.75	365	5	86	4.24	373.63	8	807.28	200	750	1930.91	2000	69.09	1600	-330.91	22.95	-4.79
50	1585.75	365	3	163	2.24	708.16	8	963.02	200	250	1921.18	2000	78.82	1600	-321.18	20.12	-4.94
125	1585.75	365	4	93	3.92	404.04	8	802.80	200	625	1831.84	2000	168.16	1600	-231.84	9.43	-6.84
75	1585.75	365	3	122	2.99	530.03	8	840.02	200	375	1745.05	2000	254.95	1600	-145.05	6.22	-10.93
150	1585.75	365	4	69	5.29	299.77	8	647.61	200	750	1697.38	2000	302.62	1600	-97.38	5.24	-16.28
100	1585.75	365	3	94	3.88	408.38	8	730.96	200	500	1639.34	2000	360.66	1600	-39.34	4.40	-40.31
200	1585.75	365	5	39	9.36	169.44	8	408.37	200	1000	1577.80	2000	422.20	1600	22.20	3.76	71.44
125	1585.75	365	3	71	5.14	308.46	8	604.06	200	625	1537.52	2000	462.48	1600	62.48	3.43	25.38
150	1585.75	365	3	53	6.89	230.26	8	487.94	200	750	1468.20	2000	531.80	1600	131.80	2.98	12.03
200	1585.75	365	4	30	12.17	130.34	8	321.63	200	1000	1451.96	2000	548.04	1600	148.04	2.89	10.71
50	1585.75	365	2	109	3.35	473.55	8	650.81	200	250	1374.36	2000	625.64	1600	225.64	2.53	7.03
200	1585.75	365	3	23	15.87	99.92	8	246.88	200	1000	1346.80	2000	653.20	1600	253.20	2.43	6.26
75	1585.75	365	2	81	4.51	351.91	8	561.61	200	375	1288.51	2000	711.49	1600	311.49	2.23	5.09
100	1585.75	365	2	62	5.89	269.36	8	485.46	200	500	1254.82	2000	745.18	1600	345.18	2.13	4.59
150	1585.75	365	2	36	10.14	156.40	8	328.26	200	750	1234.67	2000	765.33	1600	365.33	2.07	4.34
125	1585.75	365	2	47	7.77	204.19	8	405.31	200	625	1234.50	2000	765.50	1600	365.50	2.07	4.34
200	1585.75	365	2	15	24.33	65.17	8	130.91	200	1000	1196.08	2000	803.92	1600	403.92	1.97	3.93

[1] Assumed food conversion ratios are given. Feed costs to account for 50% waste husk sieved out prior to feed formulation. Opportunity costs of stocking fish are calculated based on fish weight on stocking and a market value of Rs. 25/kg. for small fish. Total benefits calculated at values of Rs. 40/kg for larger tilapia.

The sensitivity analysis demonstrated that if the assumptions of survival and cage depreciation rates are met, when fish stocking size is relatively high (e.g. 200g) and FCR low (2:1), cage-based fattening of tilapia can be profitable. Little difference in profitability between each cage design was found when the same performance variables were considered, however a labour cost (opportunity or otherwise) would be involved for necessary repairs and maintenance to the bamboo cage assumed under the model. These analyses, however, demonstrated that performance and system viability is very sensitive to food conversion ratio and feed price.

3.5 Discussion

The resource assessment indicated that there are considerable technical constraints to the introduction of poverty-focused aquaculture in the research area. The key findings were that cage materials were scarce and their properties for aquaculture unknown. Feed ingredients, however, were available, but rice bran was subject to seasonal availability and rice polish was only available in RAJ. Fish catch characteristics revealed that there was a seasonal peak in the availability of small tilapia in the *yala* season, although both USG and RAJ fishers reported year-round availability. An assumed culture system was tested for economic viability using a sensitivity analysis. This desk study demonstrated that cage-based fattening could be viable if fish were stocked at a density of $200/m^3$ in bamboo cages at an individual size of 125g and could be harvested at 250g and assuming a food conversion ratio of no greater than 5. For metal cages a profitable system would be achieved providing fish were stocked at no less than 100g and harvested at 250g based on a FCR of no greater than 4. Previously unsuccessful attempts at culturing tilapia for full cycle aquaculture have been hindered by unfavourable economics (Thayaparan, *et al*. 1982). Therefore, there was a need to test the opportunities for viable tilapia aquaculture using a short-term fattening approach instead of full culture cycles. This was an important research focus which could contribute to improved knowledge of the potential for aquaculture in Sri Lankan tanks to complement fishers' livelihoods and provide an appropriate poverty-focus.

3.5.1 Identified resources and their application

Cage materials

Conventional cage materials such as HDPE netting and knotless materials, commonly used in cage aquaculture, were not locally available and if sought had to be imported from India. The resource assessment indicated that there were some low – cost local materials that could be used for cage construction. The durability of those materials was identified as a potential researchable constraint to low-input cage aquaculture in the Sri Lankan context. Wooden cage materials as well as PVC pipes were identified during the resource assessment, however, their cost was identified as a constraint and PVC has been found to deteriorate when exposed to sunlight (Nurun Nabi, 1997). Local bamboo culms were identified as being both inexpensive and abundant. Bamboos are commonly used in other countries in Asia for cage construction, however their durability in water is short. The useful working life cited by IDRC/SEAFDEC (1987) in Beveridge (1987) suggests that bamboo is viable for between 18-24 months in freshwater. Christensen (1995) suggested that bamboo has a useful working life of 4-6 months. This depends greatly on the species and age of bamboo culm and its moisture content. Allowing for the latter estimate of durability, the economic sensitivity analysis presented in Table 3.3 suggested that cage-based fattening using bamboo - based cages was still economically viable even given a requirement for the bamboo component of the cages to be replaced 3 times per annum. Despite its short predicted working life, bamboo was provisionally selected as a cage material due to its low cost, which could potentially offset its required frequency of replacement.

Feed

Feed was identified as a significant limiting factor to cage aquaculture. The resource assessment identified a distinct shortage of dried feed ingredients available with potential use in aquafeeds. Formulated feeds were not locally available and the use of poultry feeds was rejected as some feeds were medicated, could only be purchased in large quantities and were unlikely to be economically viable. Limcangco-Lopez (1987) states that Sri Lanka is a net exporter of agricultural by-products hence producers are highly reliant on imported processed feeds.

Small minor cyprinids such as *A. melettinus* and *R. daniconus* available perennially, but dried on seasonal basis, were identified for potential use in aquafeeds. The prevalence of rice mills in close proximity to USG and RAJ villages indicated that rice bran and polish (in RAJ) were available. Rice bran, or where available, rice polish were proposed as possible constituents in the feed. Sieving rice bran in USG was found to remove large amounts of husk (approximately 50% by weight). A feed comprising of 50:50 ratio of sieved rice bran or rice polish to minor cyprinids (on a wet weight basis) was initially tested by researchers and found to be stable in water.

Livestock production is a small-scale activity in Sri Lanka contributing only 6.2% to GDP in 1998 (GoSL, 2004). Low competition from an established livestock industry assists the viability of aquaculture through reduced competition for resources, but also constraints aquaculture due to low availability of quality feed ingredients.

Cage size

Cage size has a considerable impact on economic return. A greater return per unit area is achieved by using larger cages than small cages owing to their lower capital cost relative to yield ratio. A key constraint for cage aquaculture to contribute to poverty alleviation is the capital cost of start up for the producer. Smallholder farmers undertaking cage aquaculture as a supplementary livelihood activity are unlikely to raise the capital required for construction of large cages nor required seed input at the desired stocking density to work technically. Other disadvantages include the difficulties of day-to-day management of large cages which often require numerous people to perform simple tasks. Increasing the cage size exacerbates stock monitoring and mortality removal difficulties. Cage aquaculture is vulnerable (Beveridge, 1987) and the potential for larger stock losses to occur as the result of damage to a large cage would place farmers at an increased risk and possibly into greater debt if money was borrowed to start up cage aquaculture. In contrast small cage units have potential risk spreading advantages over large cages in the event of damage or sabotage. Noting both the economic constraints and risk factors, small cages of $1m^3$ were proposed as having relevance for poverty-focused aquaculture in USG and RAJ villages. Both men and women have used small cages successfully in Bangladesh as a means of generating household income from local waterbodies (Brugere *et al*. 2000). The system met a market demand for fresh, inexpensive fish. The small size of the cages made them easier to manage and has facilitated the involvement of women in the activity as it is within their physical capabilities. An advantage of the situation in Bangladesh was that cage aquaculture was a new activity therefore no traditional gender roles had been established, although the approach still required an overtly gender-focused approach to ensure participation in more conservative areas.

Stocking densities

An advantage of cage aquaculture is that stocking densities can be far greater than those achieved in pond culture as water in cages is constantly replenished and nitrogenous wastes dispersed by the action of fish movement. This does depend, to some extent, on cage situation which must consider water quality and waste dispersal characteristics prior to site selection. A high density low volume cage culture concept (Schmittou, 1993) suggests that efficiency and performance of cage culture can be improved by stocking fish at high densities in low volume units. The high - density low volume system benefits cage producers as feeding efficiency improves, per unit profit increases and territorial behaviour exhibited by fish is suppressed at high stocking densities. This system has certain key advantages for the poor as production can be maximised in a small unit area, with lower capital and management costs than that associated with large cages or ponds. Negative aspects of stocking at high densities however include high costs incurred in the event of theft or escape. Recommended stocking densities of 200 tilapia/ m^3 prove successful in small cages (CARE CAGES, undated; Muthukumarana & Weerakoon, 1986, Guerrero III, 1980). For the reasons discussed above, the proposed research agenda focused on the concept of high-density low volume cage culture using the cages developed in Bangladesh as a model on which to develop for the Sri Lankan context. This presented an opportunity to gain maximum economic benefit from small, low cost, cages.

Seed

The situation appraisal indicated that small tilapia were abundant in the catch particularly during the *yala* season when large tilapia were less available. The potential to deposit excess fish from the catch in cages and harvest them when required was identified as a possible research focus. Methods of stocking fish were discussed although collection of fish from gill nets used in normal fishing practices were anticipated to be the principal means of fish collection. A key challenge of this approach was to minimise stress and mechanical damage to fish collected in this manner.

After identifying the available inputs for cage aquaculture a few husbandry elements required consideration prior to operationalising the cage-based fattening of tilapia system. These are considered below.

3.5.2 System husbandry

Cage installation and positioning

Beveridge (2004) advises that cages are suspended at least 4 - 5 metres above the sediment as a precautionary measure against oxygen depletion particularly when cages are moored in clusters and fed intensively where localised sedimentation of nitrogenous faecal waste and uneaten feed contributes to anoxic sediments. However, fish can be cultured in small cages placed on the bottom of ponds without such adverse effects (CARE CAGES, undated; Yang *et al*. 1996) providing that they are moved on a regular basis and that feed waste is minimised. Benthic feeders, such as prawns, have been successfully cultured in cages placed on sediments (Beveridge, 2004). Despite these examples, it is important that the interaction between stocking density, feed quality and wastage is well understood as these factors play a role in expected water quality. The simple depth survey indicated that the deepest areas of both tanks, with potentially the best location for water quality, were located at the bund and in the centre of the tank, where a trench from an old canal remained. In both tanks, depths that left cages suspended at least 4-5 metres above the sediments were found although the constraints that this poses for functional reasons i.e. lack of boat access, distance from shore and security required further consideration.

Feed administration method

Several methods of feed administration such as hand feeding, use of feed trays and pots as well as rudimentary demand feeders were presented. Beveridge (2004) reports that since cages have a smaller volume to surface ratio, food can be carried out of reach by currents and the need to minimize feed losses must also ensure caged fish have sufficient access to feed. Therefore, the method of feed administration was envisaged to take account of the fact that feed would need to be accurately delivered to avoid feed dispersal out of the cage before ample opportunity for the fish to feed was allowed. The suggestion of hand feeding fish was made. Hand feeding is preferred in some culture systems as it can be used to assess appetite and adjust feeding rates accordingly (Beveridge, 2004). Thorpe *et al.* (1990) also observed that hand feeding of salmonids in sea cages led to a more even distribution of feed.

Considering these potential advantages hand feeding was proposed. Hand feeding, despite its benefits has been criticised for being labour intensive due to the time take to deliver feed and observe stock. Other feed presentation methods such as use of feeding trays and pots were also proposed based on the experiences of the CARE CAGES small-scale cage culture project in Bangladesh. The potential for making rudimentary demand feeders was also discussed.

Stock monitoring

Monitoring fish behaviour and growth can indicate any emerging disease problems occurring within the cage population. Fish would be sampled using a scoop net. The cage design was modified sot that the net bag could be pulled up and looped onto the cage frame to form a corner pocket where fish could be observed without their removal from the cage. This procedure also could be used to determine when fish were suitable for harvesting.

Harvesting

The factors determining harvesting were an important outcome of the research. Hence, participants were left to make their own decisions about stocking and harvesting cages in order to meet their needs. Community meetings were used to discuss the possibility of harvesting cages fully or partially. A key area of the monitoring process followed cage operator decision-making.

3.6 A tentative research agenda

Tables 3.6 and 3.7 summarise a tentative proposal for a cage-based tilapia fattening system based on the materials identified drawing on experiences from the CARE

CAGES Project in Bangladesh (Bulcock *et al*. 2000). The process of community meetings in both USG and RAJ communities served to establish interest in the concept of cage-based fattening of tilapia, and highlighted key constraints to the proposed methodology.

Table 3.6 Proposed research strategy presented in November 2000, USG village

Component	Description	Rationale
Cage materials	Floating bamboo cage with nylon net mesh bag insert with kapok wood floats	Locally available material, inexpensive, easy to source. Unknown properties for cage culture
Cage size	$1m^3$	Small size cage easy to manage. Low capital and operation costs
Cage installation	Anchored in water depth > 4 metres	Assists waste dispersal Negates pollution effect of bottom sediments
Feed	Potential for fishmeal preparation for dry feed or 50:50 ratio, wet fish: rice bran to produce balls of feed	Locally available materials Can be sourced without purchase Some seasonality but availability high
Feed presentation	Hand feeding / feeding trays or pots	Permits stock observation Minimises feed waste
Seed supply	Collection of small “undersize” tilapia for stocking	Fattening to add value rather than landing at lower value Seasonal abundance of small fish and shortage of large fish in catch providing niche marketing opportunity
Stock monitoring	Scoop nets used to monitor fish growth and mortalities	Indicative of stock health Monitoring growth and harvest time
Harvesting	Harvested with farmer requirements (complete or partial harvesting)	Harvesting to meet household income requirements or exploit marketing opportunities such demand for large fish for festivities such as wedding.

Table 3.7 Proposed research strategy presented in September 2001, RAJ village

Component	Description	Rationale
Cage materials	Iron frame and 1” galvanised metal mesh	Locally available material, inexpensive, easy to source. Unknown properties for cage culture
Cage size	$1m^3$	Small size cage easy to manage. Low capital and operation costs
Cage installation	Anchored in water depth > 4 metres	Assists waste dispersal Negates pollution effect of bottom sediments
Feed	Potential for fishmeal preparation for dry feed or 50:50 ratio, wet fish: rice bran to produce balls of feed. Locally available household waste and fish waste may be added to feed	Locally available materials Can be sourced without purchase Some seasonality but availability high
Feed presentation	Hand feeding / feeding trays or pots	Permits stock observation Minimises feed waste
Seed supply	Collection of small “undersize” tilapia for stocking	Fattening to add value rather than landing at lower value Seasonal abundance of small fish and shortage of large fish in catch providing niche marketing opportunity
Stock monitoring	Scoop nets used to monitor fish growth and mortalities	Indicative of stock health Monitoring growth and harvest time
Harvesting	Harvested with farmer requirements (complete or partial harvesting)	Harvesting to meet household income requirements or exploit marketing opportunities such demand for large fish for festivities such as wedding.

Chapter 4 goes on to describe the community meetings held to discuss the potential for cage-based fattening of tilapia and the participatory technology development process and outcomes that followed.

Chapter 4 Participatory Technology Development; research agenda

4.1 Introduction

The previous chapter defines a tentative aquaculture research agenda developed from the findings of the participatory situation appraisal and the resource assessment. In order to assess if cage aquaculture might have potential as a supplementary livelihood activity, meetings were held in each community to discuss the concept with local people. Key inputs for aquaculture such as feeding, seed, materials for cage construction and water availability had been initially assessed in each location by the researcher in Chapter 3.

It has long been recognised that greater participation by those who are to be affected by research or development can improve the efficiency, effectiveness and sustainability of those processes and their outputs (Campbell & Salagrama, 2000). Previously used transfer of technology models perceived the process of technology development as essentially a passive, linear process (Platt & Wilson, 1999). This process misses the context-specific problems that can be encountered and is exactly the reason why the transfer of technology approach to development has failed in many cases. When research is carried out by end-users, then the generation and application of knowledge in the development process become inseparable (Haylor *et al*. 2000). Participatory technology development (PTD) improves knowledge of context and gives participants the opportunity to own the process of developing and adapting the technology to meet their needs and prevailing local conditions. PTD refers to approaches that aim at strengthening local capacities to experiment and innovate. Farmers are encouraged to generate and evaluate technologies and to chose, test and adapt external technologies on the basis of their own knowledge and value systems (Reinjntjes *et al*. 1992). This approach enables both researchers and farmers to reach a joint understanding of the characteristics and conditions within the community and the fishery, define research priorities and identify benefits and constraints according to local knowledge. The process of participation also enhances the self-confidence of farmers by taking their contributions seriously so they can develop solutions to address their own needs. In adopting a participatory approach, we aimed to improve the relevance of the technology to the local context and stimulate the process of adoption where appropriate. Participation was sought in identifying a potential research focus, designing and modifying a research agenda and experimenting with aquaculture *in situ*. A major assumption was that participants would contribute their own labour.

This chapter will outline the methods that were used to develop an appropriate research agenda and the process of engaging communities in collaborative participatory research in USG and RAJ communities. An attempt is made to highlight the real complexities of initiating research in new communities when trying to make participation equitable.

4.2 Methodology

The process of introducing cage-based fattening of tilapia comprised several steps. The preparation of the case for aquaculture and initial identification of cage materials was undertaken by the researchers. A succession of community meetings identified any potential conflicts and constraints to cage aquaculture and new methods of project implementation were discussed. The meetings conducted in USG village took place in November 2000 and represented the first attempt at participatory research. Community meetings conducted in September 2001 preceded the second intervention in RAJ village. The methods used were slightly different in each village according to the local context.

4.2.1 Organising village meetings – USG village

Cage aquaculture is a relatively unknown practice in Sri Lanka and has mainly been conducted through on-farm government research trials. The objectives of the village meetings were (1) to explain what cage aquaculture was and how it worked and (2) identify if there was a potential role for cage based fattening of tilapia. An initial meeting also sought to establish the level of interest in participation. Further meetings were subsequently conducted in both communities to gauge levels of interest and highlight any possible conflicts and constraints arising from aquaculture intervention. The initial community meeting sought to include all primary stakeholders; men and women, farmers and fishers and farmers and both younger and older generations.

Targeting the stakeholders and arranging meetings was undertaken using the following steps to reach the maximum number of people and reduce bias towards any particular group:

(1) Informal discussions with local key informants about a proposed meeting date to assess if this conflicted with other village activities such as fishing society/farmers' organisation meetings, weddings or funerals.

(2) Selecting a local venue impartial to religious background and central to the village

(3) Arranging an appropriate date and time of day to minimise impact of agricultural and household activities and reducing conflict with fishing activities or rest periods.

Key informants identified by researchers and other villagers during the situation appraisal, were interviewed. These informants included the president of the Fishermens' co-operative society and the farmers' organisation. On reaching a consensus amongst key informants, the meeting dates, places and times were circulated around the village by word of mouth, announcements made at the end of fishing society, farmers' organisation and DDS meetings[1] and the distribution of posters in Sinhala. Key members of the community such as the president and secretary of the fishing society, the Samurdhi officer and local shop owners spread news of the meeting by word of mouth.

During the course of arranging meetings and in particular after the first meeting a number of other community divisions became evident through low participation. Divisions between the in-coming and out-going fishing society presidents and their support base were identified as a causal factor. This relationship highlighted fissures within the fisher-farmer community based on both presidential support and political allegiance. Our initial contact, the out-going fishing president lived in the new fishing village, was a close associate of the former fisheries extension officer and he arranged the venue in his own community. This meeting failed to attract as many people as possible for two key reasons; firstly, disgruntlement between first generation residents

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[1] Targeting the DDS meeting (or Death Donation Society meeting) was of particularly high impact as each family within the village must send a representative or face a fine from the Society, consequently meetings have a high turn out.

of USG main village and the second generation, residents of the new fishing village meant that some fishers did not attend the meeting out of protest or did not hear about the meeting. This highlighted that residents in the main USG village felt increasingly marginalized by the provision of subsidies for housing to the new fishing villagers. In addition there were accusations of embezzlement against the out-going fishing society president and the fisheries extension officer who managed the fishing village construction project. Key informants mentioned that this had caused widespread resentment and had contributed to the divisions between the new fishing village and the old village residents. Polarised political differences between People's Alliance (PA) and the United National Party (UNP) supporters within the village were also identified and had to be taken into account when rescheduling appropriate meeting times and venues. As word of mouth, relied upon to communicate previous meetings, failed to ensure equitable access, further meeting arrangements were made using different methods.

As literacy levels were high ten A3 size posters were prepared in Sinhala language and displayed outside local shops and other areas where people congregated. Photos of fish and fish cages were put on the posters to attract attention and outline the purpose of the meeting. New posters were made for each subsequent meeting to promote an ethos of transparency and inclusiveness of the project's approach. The research team also maintained a high presence in the village, making daily visits to landing sites, shops and householders to ascertain if they knew about the meeting and to answer any questions.

Venue selection

Agreeing a suitable venue with a large catchment area presented some challenges. Some villagers and shop owners suggested attending village meetings such as the Death Donation Society meeting (held in the Buddhist temple) and talking to people after that meeting concluded its business. A key benefit was that each household had to send a representative to the meeting; therefore the audience for dissemination was large. Two key constraints to this approach were identified. Firstly, people were normally eager to leave in order to get back to work at home and secondly, culturing fish was something which was against Buddhist beliefs and the temple would not be an appropriate forum for this topic.

An initial meeting was held under a large tree in the newly constructed fishing village, under advice from the fishing society president, who deemed this to be a well-known area to convene meetings. Aside from the social and political reasons stated, this attempt failed to attract a fair representation of the villagers due to its distance from the main village. A further meeting was arranged at the village school which was easily accessible from all areas of the village and was sheltered in the event of rain. This also had the advantage of a blackboard which was used to illustrate how cage-based fattening of tilapia could be piloted as a concept in their village.

The meeting in USG began with the Sri Lankan research team presenting the findings of the situation appraisal to provide an overview of the livelihoods context and was used stimulate initial discussions. Once the 'problem situation' had been established, the concept of fattening small tilapia in cages was introduced. The researchers explained how this may be accomplished using locally available materials identified at the resource assessment. Visual support explaining how cage-based fattening of tilapia could be undertaken was achieved by drawing diagrams on the blackboard. This then became a focus for discussion. The availability of resources was discussed with attendees. Potential conflicts and constraints to cage aquaculture were discussed with participants and the advantages and disadvantages of cage culture methods debated. A list of interested participants was taken at the end of each meeting and participants were contacted thereafter.

4.2.2 Organising Village Meetings – RAJ village

The objectives of village meetings remained the same in RAJ as in USG village however the small village size made organising meetings easier. RAJ village had a meeting hall in a central location which was used for all meetings and was therefore selected as the appropriate venue for project meetings. This venue was central to the village and regarded by villagers as impartial. Key informants such as the head of the Fishermen's Co-operative Society and the President of the village women's group were consulted to ensure that no other village meetings coincided with the proposed project meeting. A suitable time of day was chosen to ensure that as many people as possible could attend without interfering with household chores, fishing or rest periods. Meetings were normally conducted early in the afternoon as fishermen were rested, lunch had been taken and women had collected children from school and completed housework by this time.

A series of meetings in RAJ village took place after participatory trials were initiated in USG village (research framework, Chapter 1), the methods used in the village meetings in RAJ were changed to integrate new knowledge and experiences. A cage operator from USG village came the initial meeting to talk about his experiences of cage culture and to stimulate discussions. Diffusion investigations show that most individuals do not evaluate an innovation on the basis of scientific studies or its consequences. Instead most people depend on subjective evaluation of an innovation conveyed to them from other individuals like themselves who have previously adopted the innovation (Rogers, 1995). This method was advantageous as villagers gained an opportunity to speak to a rural person with a similar cultural background. This also helped to break down the barrier of the 'locals' and 'outsiders' through this process. The use of photographs of fish cages was a further development on the method employed in USG village. Plate 4.1 shows posters being examined by women in an initial community meeting. The photos were mounted on posters with the task performed in each picture annotated. Photographs of cage operators in USG village were used to visually convey what cages were and how other Sri Lankans operated fish cages. Photographs taken from the CARE CAGES project in Bangladesh were also mounted on posters with the tasks being performed annotated below. They depicted both genders' being involved in cage aquaculture to demonstrate that this was an activity that was also acceptable for either men or women to undertake. The posters were left in the village for further dissemination after the meeting concluded.

Plate 4.1 Women at RAJ village view cage culture posters depicting cage aquaculture in Bangladesh and USG village, Sri Lanka

Format of community meetings

The Sri Lankan research team presented the findings of the situation appraisal focusing the participants on identified issues contributing to livelihood vulnerability. The team highlighted the seasonality of fish catch and the demand for large tilapia amongst vendors. After explaining the potential opportunity that aquaculture posed, the team presented the concept of cage-based fattening of tilapia in the meeting. In both villages drawings of fish cages and cage stocking were used to illustrate cage aquaculture, how it worked and how fish were stocked and harvested. This introduction was then followed by an open question and answer session. During the course of the meeting, the proposed research agenda was presented and potential conflicts and constraints to the proposed methods identified. The cage design proposed by this stage in September 2001 had changed from the bamboo box design used in USG to a galvanised metal mesh cage. All other methods remained broadly similar. Several constraints were noted and resulted in changes to the research agenda to accommodate participants' views.

After the meetings, 24 people stated their interest in cage operation. Twelve out of the twenty-four people were women from the SEDEK[1] organisation within the village. The project fabricated 24 cage frames that were made from 10mm twisted iron bars, which were welded and painted with anti-corrosive paint by a local welder in Galgamuwa. The cage materials such as polystyrene floats, galvanised metal mesh,

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[1] SEDEK is a religious development organisation that supports women to undertake small-scale enterprises such curry and chilli powder production.

wire cutters, floats and PE rope were distributed within the village and people fabricated their own cages.

The provision of cages was subsidised by the project, with cage materials given to participants in order to construct their own fish cages. As funds limited cage construction a maximum of 24 cages were allocated for RAJ village. A list of participants interested in cage operation was compiled after the second meeting and cages allocated at random.

4.3 Results

People who attended the meetings in each community approved the concept of cage-based fattening of tilapia. However, there were marked differences between the potential constraints to resource availability and to the participation of women in USG and RAJ. In this section the outcomes of community meetings are presented separately for each village. The results indicate the number of participants in attendance at the village meetings (disaggregated by gender) and the possible conflicts and constraints to the proposed research agenda which were identified.

4.3.1 USG village

The gender and number of participants at the community meetings was monitored in the initial stages. The attendance figures are outlined in Table 4.1. The meetings were male dominated. The first meeting was attended by fifteen members of the community and comprised both farmers and fisher-farmers. The second, larger, meeting held in the school, arranged using different methods of dissemination, attracted forty-three men and five women. Women left shortly after the meeting began. When the research team followed this up with women afterwards they felt that the proposal was more relevant to men as they were principally involved in fishing; this being a pre-requisite for participation.

Table 4.1 Attendance figures disaggregated by gender at USG village.

USG	1st meeting			2nd meeting		
	Total	***Male***	***Female***	**Total**	***Male***	***Female***
Attendance	15	15	0	43	43	5
Location	Large tree at the New Fishing village			School (Central to Track 4 village)		
Time	2 pm			2 pm		

Once cage operators were randomly selected from the list of interested participants a further meeting was held to discuss cage design and materials. Key aspects of modifying the proposed cage-based fattening method related to resource use and availability. During the course of discussions with the participants in attendance researchers asked questions about the availability of resources within the village. This opportunity was used as a means of crosschecking information gained in the situation appraisal and resource assessment. The resources identified as having a potential role in cage aquaculture were discussed and participants suggested further local materials with potential roles in cage fabrication.

Cage materials

In addition to bamboo, participants identified other woods that could be used to construct cage frames. These included materials such as “kenda” (*Macaranga* *peltata*), "sapu" (*Michela champaca*) and pine which were identified during the resource assessment. After further discussion, these woods were rejected for use as potential cage materials on the basis of their relatively high cost. Bamboo had been suggested by the researchers for cage frame construction owing to its high availability and low cost. Participants verified that bamboo culms were widely available in homesteads around the village and agreed that it could be used initially. Although participants expressed a lack of knowledge of fish cage construction they had extensive experience of working with bamboo for other construction purposes.

During the meeting participants suggested that small mesh gill nets used for catching minor cyprinids could be fashioned into net mesh bags to contain fish. However, the concept of using the net bag alone warranted reconsideration. Fishermen highlighted the need for the cages to be protected from predators. Monitor lizards and otters, which were responsible for destruction of fishing nets, could be attracted by the fish held at high density in cages. Owing to the lack of alternative cage materials at this point, other than chicken wire mesh with a short working life, the cage design was amended to account for predation; the net bag being protected by split bamboo attached to the main cage frame.

Feeds

The possibility of drying fish over a 7-day period using a method developed by (Amarasinghe *et al.,* 2002) was compared with using fresh fish in feeds and explored and developed in participant meetings. Locating cassava flour (a binding ingredient) was also discussed, although its low availability was identified as a constraint during the assessment.

Cage installation sites

Consideration of cage security was the main factor in determining the site of cage installation. The proposed modified research agenda developed from meeting outcomes is presented in Table 4.2.

Table 4.2 The proposed research agenda, key constraints identified and action planned in USG village.

Resource Required	Proposed method	Identified Constraints	Action planned
Cage materials	Small scale net cage culture Bamboo frame suspending 1m^3 nylon net bag made from local fishing net	Damage to net bags by monitor lizards	Design amended to box-shaped net cages covered with split bamboo.
Cage installation	Cages to be installed in water > 2m deep to facilitate waste dispersal and avoid obstruction	Cage security; greater distance from landing site potentially increasing chance of theft	Cages installed near to landing sites for security and convenience
Feed preparation	Minor cyprinid species could be caught, dried and ground to prepare fishmeal, mixed with rice bran and cassava to make a farmer-made feed such as that of (Ariyaratne, undated) (Amarasinghe *et al.*, 2002) or Fresh feed prepared using 50:50 fresh minor cyprinids and sieved rice bran	Dried fish difficult to grind using household equipment due to rubbery/oily consistency. Fresh fish ground easily using household equipment. Cassava not available in the village due to elephant damage to crops	Fresh trash fish ground with sieved rice bran in a 50:50 ratio to make a food ball
Feed presentation	Feeding methods variable according to preference. Methods suggested: Hand feeding Feeding pot or tray	Feeding by hand deemed too time consuming	Feeding pots made from locally available clay yoghurt pots. Range-finding exercise by cage operators to share feeding experiences
Stock monitoring	Cage operators can use rulers to measure the size of fish at stocking and record them in the notebooks. Males could be stocked preferentially as they will grow faster than females in culture systems	Choice of fish stocked in cages will be made according to physical condition i.e. dead or alive	Cage stocked with mixed sex tilapias. Operators agree to measure size and number of fish stocked.
Fish stocking	Stocking small tilapia when there was an excess of small fish available. Live fish removed from gill nets and stocked in cage Suggested stocking density of 200 fish per cage	Potential gill damage to fish during removal from nets	Fish kept alive in canoes and handled carefully and stocked in cage. Operators would attempt to stock at optimal density

4.3.2 RAJ village

As most preliminary problems with the cage design had been addressed in USG, less development of the cage design took place in RAJ. Twelve women and one man attended (the fishing society president) the initial meeting. This was due to a misconception amongst men that the meeting was intended for women only. Once it was established that the meeting was open to both men and women a second meeting was arranged to discuss cage culture collectively. The overall attendance at the second meeting was higher, attended by 21 men and 12 women from the community. These attendance figures are presented in Table 4.3.

Table 4.3 Attendance figures disaggregated by gender at RAJ village.

RAJ	**1st meeting**			**2nd meeting**		
	Total	***Male***	***Female***	**Total**	***Male***	***Female***
Attendance	13	1	12	33	21	12
Location	Community meeting hall			Community meeting hall		
Time	2 pm			2 pm		

The meeting served to highlight the potential opportunities and constraints to participation in cage-based fattening of tilapia. Many of the constraints raised regarded access to cages, particularly for women. The proposed research agenda is presented in Table 4.3. These issues were overcome to facilitate the inclusion of women in aquaculture research.

Table 4.4 The proposed research agenda, key constraints identified and action planned in RAJ village

Resource Required	**Proposed Method**	**Identified constraints**	**Action planned**
Cage materials	Use cage constructed of galvanised iron mesh with feeding hole cut in top. Construction of cage to be undertaken by cage operators. Polystyrene floats used	Potential scale loss and abrasion to fish due to small cage size and cage material.	No negative effects of this type in USG using cages. Agreed to test galvanised metal mesh cages.
Cage installation	Cages to be installed in depths of water over 2 metres for good water exchange and to avoid cages being affected by sudden changes in tank water levels.	Women unable to access cages using boats. Men concerned that high waves and windy conditions make cage operation in deeper areas of the tanks difficult. Cage security flagged as an issue. Cages can be relocated in response to decreasing tank water levels and floats and anchor applied to adapt to increasing water level	Women will install cages at the inshore area of the tank wading in to access them for feeding. Participants more confident if cage is close to the tank edge i.e. closer to and in sight of their home. Some participants intend to wait until tank water level increases when cages can be sited close to the home before cage installation for security reasons.
Feed preparation	Minor cyprinid species could be caught, dried and ground to prepare fishmeal. This could be mixed with rice bran and cassava to make a ball feed	Dried fish difficult to grind. Large quantities of fish waste from processing, small minor cyprinids and by catch species such a *G. guiris* widely available in the village. Cassava not locally available	Fish wastes and minor cyprinids from Sirimapura rice mill can be used in feed preparation. Household food waste can also be used. All ingredients readily available in the village, with the exception of cassava flour
Feed presentation	Hand feeding to observe feeding response and/or presentation of feed in a tray/pot. Feeding mesh bags made from mosquito nets placed inside the cage to reduce feed losses	-	Feeding according to operators preferred choice using either hand feeding, feeding pot or feed bag
Stock monitoring	Cage operators to measure the size of fish at stocking using a supplied ruler and record data in designated notebook.	Fish size could be estimated. Measuring too difficult to do on boat. Number of fish could be recorded in record book once participant has returned to household.	Agreed estimation of fish size would be sufficient. Participants to date and count stock in and record cage harvesting details in notebook provided
Fish stocking	Stocking small tilapia that would otherwise be landed, when there was an excess of small fish available. Optimal stocking density of 200 fish per cubic metre. Stock fish which are very lively	Women expressed difficulty in catching small tilapia independently of men, but were confident of assistance from other fishers either husbands and sons or friends.	Participants would collect fish and stock cages when suitable. Fishermen would assist female-headed households not involved in fishing to stock their cages.

At the end of the meeting the research agenda was adjusted for participants to operate cages according to their own convenience. For women, critical aspects of cage culture such as obtaining fish for stocking was not perceived as a constraint as they thought that relatives or friends would be able to assist them to stock their cage. This was a greater concern for female-headed households where fishing was not undertaken as a livelihood activity, due to lack of gears boat access and ownership and their inability to swim. The positioning of fish cages in deeper areas of the tank was highlighted as a constraint by women who were unwilling to borrow boats and paddle out to cages installed in deeper water. As a result women indicated that cage operation at the inshore areas of the tank would be more acceptable for them as they could wade out to cages for feeding and maintenance. The posters showing women operating cages in this way in Bangladesh provided the impetus for this decision.

Cage positioning within the tank was also an important issue for men. They had some reservations about cage security if cages were sited offshore and were not visible from the homestead. Where to site cages was ultimately left to participants as this was to meet their needs however awareness of the advantages and disadvantages informed their decision-making

Participants at the meetings identified feeds readily available in RAJ. Catching small tilapia and minor cyprinids was commonplace. The use of dried fish was also questioned as participants felt that the fish were too oily to be crushed for fishmeal preparation. For this reason fresh fish was deemed the most acceptable form of fish with which feed could be prepared. The participants also indicated that household food waste could also be incorporated to form a semi-intensive feed. Rice polish availability was established as being relatively high. Occasionally, some participants purchased rice polish to feed pigs and chickens. Again, the advantages and disadvantages of using fish in the feed were discussed for participants to assess according to their circumstances.

4.4 Discussion

In USG the presentation of the situation appraisal outlining the context and the potential role of cage-based fattening of tilapia was well received and participants gave considerable input to the proposed research agenda, adapting it to meet their needs. This included revisions to the cage design, cage location and feed preparation method. The constraints identified and subsequent modifications could not have been pre-empted prior to intervention had a more top-down approach been used.

Arranging community meetings highlighted some gender related and other social constraints to participation. This was particularly relevant to USG village where women were not interested in aquaculture research and consequently did not attend the community meetings. Organisation of meetings in the community had to be rethought in order to take into account the biases of key informants and endeavours made to promote transparency. The process of organising meetings in USG village highlighted divisions within the community between residents of the main village and the new fishing village as well as intergenerational and political differences. Community cohesiveness in RAJ village appeared greater and preconceived gender roles less entrenched. This was perhaps due to their coastal origins where women are far more actively engaged in fishing and fish processing than in the more traditional Singhalese communities.

4.4.1 Gender issues

Cultural norms of gender roles can be a restriction to women's participation. Differences in the attendance of women in meetings held in USG and RAJ villages were mainly related to cultural norms; one of the processes indicated within the DFID Sustainable Rural Livelihoods Framework.

The lack of women's presence in the pre-intervention meetings warranted some attention. Over time fishing in USG and other communities around inland irrigation tanks has developed as a male dominated activity. Challenging long established gender roles will take time to achieve and although identified as a constraint was not within the remit of the project. Lack of participation by women may indicate a disinterest in engaging in aquaculture or fisheries related activities rather than a lack of knowledge or capacity to attend meetings. This constrains women in other cultures for instance, where religious restrictions affecting women's mobility play a role in, and contribute to, their poverty i.e. *purdah* in the Islamic faith (Amin, 1997). To some degree women may have accepted the gender division of fishing as the norm and engaged in alternative activities such as livestock keeping, cadjun retting and home gardening. The negative religious implications of fishing may also have prevented women's involvement in fishing. In this context women may have related the abandonment of religious beliefs through involvement in fishing to poverty. The fact that many women in farming communities cannot swim may have played some role in their lack of direct involvement in fishing on a par with men. Women's lack of participation in the meetings may also have been explained by lack of awareness among women of their potential role in aquaculture. Women can be involved in other care-taking roles in aquaculture (Shelly & D'Costa, 2001) although this may increase their work burden (Brugere *et al*. 2000).

At RAJ women were instrumental in both organising and attending meetings. The gender roles in fishing in this community appeared to be less well defined. Women participated in all aspects of fisheries related activities but rarely fished alone. Some husband and wife fishing pairs were observed, although they were the exception rather than the rule. The reason for this practice was primarily for retention of income from the whole catch within the household rather than with a partner from another household. This indicates that the involvement of women in fishing activity in this instance is more of a household strategy rather than a manifestation of their empowerment.

Women who attended the community meetings in RAJ were members of several societies promoting livelihood diversification activities. These are discussed in Chapter 5. It is perhaps their participation in these societies which has increased their confidence and awareness of potential income generating activities coupled with the relaxed definition of gender roles which distinguishes the participation of women in this community from that of USG. As a predominantly Christian community the lack of religious prohibition of fishing, associated with the Buddhist faith in particular, may have contributed to removing some cultural constraints for women in fishing.

4.4.2 Other stakeholder issues affecting participation

Political allegiance and internal rifts between fishing society members were revealed through the community meetings. In USG village this was a potential constraint to our initial targeting of groups of people to attend meetings. This was surmounted by recognition of the problem and initiating a more public approach to dissemination methods. This highlighted a ubiquitous issue in development where elites, in this case people with higher social status (the outgoing president of the fishing society), attempted to appropriate benefits for their friends and relatives for their gain. It also underscores the importance of political and social capital in rural livelihoods. In RAJ this issue seemed less pronounced and may have been indicative of greater community cohesiveness. This is perhaps accounted for by two features of this community: (1) the cultural isolation of RAJ villagers compared to other Buddhist communities which surrounded them or (2) the small village size which may induce people to maintain convivial relationships with their neighbours.

4.4.3 Who can participate?

Due to a pre-requisite of access to feed and fish seed and ability to access the cage *in situ* the proposed aquaculture system was to a large extent self-selecting in profile of participants who could get involved. As fish for stocking cages were derived from their own excess fish catches and cages were likely to be floated to accommodate water level movements, by its nature the proposed system was more interesting to those with access to both live fish and a boat. Therefore this system was more appealing and relevant to fishers and fisher-farmers, principally men. The involvement of all members of the community could not be expected as only certain members of the community had access to enough resources of the right sort to participate. This highlighted the fact that the poorest people lacking in assets could not participate in aquaculture. Information about the proposed system given on posters prior to the meeting may have screened out potentially interested community members such as non-fishers and women. This emphasizes the case that cage aquaculture may not be appropriate for everyone within a given community, and is just one possible activity which may contribute to improving livelihoods and reducing vulnerability for a sub-section of the community. Despite the exclusion of some potential beneficiaries, but given that the majority of households had fishing or fisher-farmer livelihoods, the proposed cage-based fattening of tilapia system could benefit most households within each target community.

4.4.4 Identified risks and researchable issues

The concept of fattening ‘wild’ fish caught from the fishery was a key researchable issue as these fish had not been selected for specific characteristics such as fast growth, which may be associated with hatchery reared fish. In this respect, the characteristics of the tank - caught tilapia and their performance in aquaculture was unknown as this had not been attempted previously.

A major assumption was that people would be willing to participate in aquaculture research. The fact that participants were willing to undertake a research project with more than one unknown variable indicated that they were to some extent taking a risk. The labour time contributed to cage maintenance, feed preparation and the opportunity cost of stocking are just some of the risks which participants were willing to undertake in this type of research. Participants also undertook a social risk as the failure of the activity may have negative social implications within the community. The main risks identified in community meetings principally related to the tradeoffs between optimising technical efficacy and manageability for participants.

The community meetings held in both villages served to identify several constraints to the proposed research agenda which was duly revised to accommodate participants' views with the advantages and disadvantages of the methods proposed discussed in some depth. In both villages participants seemed to regard social needs above the possible optimisation of the technology. This was reflected in the participant's cage site selection and their feed formulation strategy. In USG and RAJ farmers rejected the proposal of drying minor cyprinids using the methods of (Amarasinghe *et al.* 2002) and Ariyarathne (2001) citing their lack of confidence that those species of fish could be dried to a sufficient degree under local conditions. They also felt that the drying process was too labour intensive.

Fish drying was also constrained by monsoon rainfall as the wet conditions hinder the ability to dry fish outdoors. The shortage of cassava tubers and cassava flour in both villages was a constraint to feed binding, however, using excess boiled rice was identified as a substitute. A major consideration was the use of feed prepared from ground, wet fish, which would inevitably contain a higher moisture content than a dried feed on a weight for weight basis and could lead to high food conversion ratios.

Traditionally agricultural and fisheries extension has followed a top-down approach in Sri Lanka with established performance such as input requirements and yields, being disseminated to farmers after on-station research trials. Once technical proficiency is established and known yields are observed, the farmers then chose to adopt and adapt the systems in their own process of adaptive research. This typically leads to farmers attempting to reduce input costs but often at the cost of sub-optimal performance.

Convenience or risk reduction may be a more important consideration to farmers than optimising yields and / or financial returns

Rather than focus on one aspect of the production system such as growth, stocking density, feed quality or technical cage performance, the research process sought to understand multiple parameters under the conditions managing the activity. The systems approach to this research outlined in Chapter 1 directed this aspect of the project into understanding a complex problem situation, identifying key characteristics of the problems and seeking ways in which the problem of poverty, and in particular livelihood vulnerability, could be reduced. The contribution of cage-fattened tilapia to poverty alleviation needed to be examined outside of the technical sphere of thinking, therefore a livelihoods approach based in 'soft' systems thinking was used to establish the impacts of the technology on both the household and the wider community through the interactions with vendors and market-level implications. The parameters of the system and its socio-economic impacts are outlined in Table 4.5.

Table 4.5 Researchable parameters in poverty focused aquaculture intervention

Sector	Researchable issue
Technical	‘Fattening’ of ‘wild’ fish on locally prepared feed
	Durability of low cost, local cage materials
	Efficacy of farm-made aquafeeds in supporting cage aquaculture
Social	Household-level contribution to income
	Contribution to reducing household vulnerability
	Complementarity of cage aquaculture with other household activities
Economic	Economic viability of cage-based fattening of tilapia in under farmer managed conditions
	Market acceptability and pricing of cage produced tilapia

From this stage adaptive research was undertaken by participants to see what could be achieved with the resources (hardware), their own ‘local’ knowledge (software) and outside information that they had gained through the community meetings and interaction with research staff.

Chapters 5 and 6 present the process of participant adoption behaviour, cage management strategies and the analysis of cage-based fattening of tilapia in household livelihoods across a range of differing livelihood typologies in both of villages.

Chapter 5 Farmer adoption of cage-based fattening of tilapia

The previous chapter identified and discussed the potential constraints to aquaculture in both USG and RAJ villages. A research agenda was developed with participants to ‘fatten’ tilapia caught from perennial tanks using farmer-made feeds. This chapter examines the extent to which technology was adopted and adapted by participants in both villages and identifies constraints to, and benefits of, adoption of the culture system. Farmer adaptations to the technical agenda through the research process are also discussed.

In January 2001, around the same time as cages were initially introduced in USG, a crack down on under size fishing meshes and illegal gears and a ban on night fishing occurred. This led to a decrease in the catch of small tilapia. However the situation reverted back to the use of illegal meshes within a period of 3 months. It is against this background that cages were introduced in USG. Although a similar ban had been implemented in RAJ in January 2001 fishing was unaffected by the time the intervention began.

5.1 Introduction

A common, and sometimes costly, misconception is to attribute economic success to “high technology” (i.e. high levels of research and development or large commitments of scientists and engineers) rather than complexity (Rycroft & Kash, 1999). The success of aquaculture as a method of reducing livelihood vulnerability depends on its viability in both technical and socio-economic terms.   Phases in the innovation process normally begin on-station or in a laboratory with a period of product development and testing prior to extension. An initial adaptation phase occurs where adopters initially use the technology. This is followed by an 'expansion' phase where technology is integrated and comes into general use. The final phase in this process is disappearance where the technology is seen as standard practice and loses its status as innovative. The transfer of technology model resembles this with a process where research is conducted first within the universities, then delivered to extensionists, who in turn promote the technology to farmers (Chambers & Jiggins, 1986).

This research framework skips these initial phases of on-station research and development and takes the concept of cage-based fattening of tilapia directly to the intended end users to develop the technology *in situ*. In agriculture resource - poor farmers continually experiment, adapting technology to meet their needs. This has often led to disillusionment amongst agricultural scientists and extensionists whose role involves developing and promoting the most efficient yield optimising technologies. In the past this may not have involved much consideration of farmers' needs or motivations. Farmers are seen to either passively adopt or not adopt but not to adapt the new technology themselves (Rogers, 1995). In the past fifteen years there has been increasing recognition in agriculture of the role of farmers' knowledge and greater emphasis placed on understanding their objectives rather than those of the researchers and technologists. A paradigm shift in the way agricultural research and development is done has occurred, away from traditional on-station research followed by transfer of technology to a more complementary and participatory on-farm "Farmer First" approach. This approach aims to comprehend the needs and motivations of farmers in developing countries and to develop appropriate technologies with farmers to meet their needs. Biggs (1989) describes a multiple sources of innovation model which recognises that farmers, rather than being the passive recipients of proven technologies, are active *participants* in the adoption process, struggling to give their own unique meaning to the innovation as it is applied in their local context.

In many cases, large-scale production oriented development interventions led to what researchers may deem as sub-optimal, uneconomical production and projects have been branded failures when these parameters are used to assess their success. The alternative view is that farmers have adapted, modified and innovated, using technology to their meet their own livelihood objectives. Farmers' rationale for this may be due to risk avoidance, economic hardship and / or socio-cultural barriers. Rhoades (1989) proposes that farmers do not think in terms of adoption or non-adoption as we do, but select elements from technological complexes to suit their constantly changing circumstances and that farmers preferred to adapt and modify the technology on a small-scale rather than scaling up immediately as a risk avoidance strategy.

In this chapter of the thesis the adoption of cage-based fattening of tilapia by fisher-farmers in USG and fishers in RAJ and the adoption process experienced in each village is presented. Also presented are the key factors which influenced adoption using qualitative methods.

5.2 Methodology

Key objectives of the study were to:

- Assess the technical feasibility of cage-based fattening of tilapia with operators in two differing contexts
- Ascertain to what extent the technology is compatible with existing livelihoods activities
- Assess the extent to which cage-based fattening of tilapia contributes to reducing seasonal livelihood vulnerability in operating households.
- Evaluate vendor and consumer preference for cage fattened fish.

The following methods were used to meet these key objectives.

5.2.1 Monitoring of farmer-managed research

The reasons for adoption and rejection of the technology were investigated to understand key socio-economic and technical constraints. Pro-innovation bias in diffusion studies described by Rogers (1995) where it is in the interest of the promoter of the technology to report its success, usually means that the reasons for failure to adopt technologies are under reported. It was our view that these factors were critical to understand for problems to be addressed in future studies to develop appropriate technologies for the rural poor in Sri Lanka and elsewhere.

Rogers (1995), in his treatise on diffusion of innovations, states that between 49-89% of variation of a technologies adoption rate can be explained by the following:

Technological complexity: the perceived level of knowledge required and complexity of knowledge required to adopt the new technology

Relative advantage: the degree to which an innovation is perceived to be better than the technology is supersedes

Observability: the degree to which the results of an innovation are visible to others

Trialability: the extent to which an innovation can be experimented with on a limited basis

Compatibility: the degree to which the innovation is perceived as consistent with the existing values, past experiences and needs of potential adopters.

Consequently, the following hypotheses about the adoption of the cage system were made:

- Explanation and basic training in aquaculture through on-site training sessions and community meetings would reduce participant perceptions of technological complexity and promote adoption.
- Ownership and operation of a cage would provide the operator with some degree of relative advantage i.e. the ability to hold fish and feed them would supersede their current use of small mesh holding bags to hold fish prior to sale. The ability to exploit marketing opportunities or smooth income seasonality was also viewed as another relative advantage of the system.
- Cage aquaculture is highly visible which may have positive social benefits for successful operators. Conversely failure to achieve positive results may have negative social implications

- Trialability is restricted as fish require basic feeding of a reasonable quality to grow. In this regard, expectations of farmers may not be met if feeding is compromised.

- Adoption will be high as the technology is highly compatible with the needs of fishers in both communities.

Adoption and discontinuance of cage-based fattening of tilapia was observed by closely monitoring practice over a prolonged period of 8 months in RAJ and 12 months in USG. When operators discontinued cage operation they were interviewed to identify their reasons for discontinuance. At RAJ the results are disaggregated by gender to emphasise the differences in cage operation experience between male and female operators and highlighted the link between gender and capacity to operate cages.

Cage operation monitoring

The method of stocking fish in cages and fattening then was agreed with farmers prior to cage installation through a series of village meetings outlined in chapter 3. Our initial interest focused on measuring as many parameters of system performance as possible. This aimed to establish the economic viability of the system *in situ* i.e. as farmers used the cages rather than their optimum performance. In order to achieve this, food conversion ratio (FCR)[1] and specific growth rates

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[1] Food conversion ratio (FCR) was calculated as the Total amount of food fed (kg)/Increase in biomass (kg).

(SGR)[1] were calculated to assess the actual operating cost of feeding and the time period from the start of the culture system to harvest under farmer conditions. The contribution of these factors to economic viability of the system is incorporated into the sensitivity analysis in Chapter 3. One critical assumption to measure this was that fish were stocked at one point in time and at harvesting measurements could be taken. Within a short period of time it emerged that farmers' stocked small numbers of fish over time, therefore this method could not be used to calculate FCR or SGR for the cage population and would require independent quantification.

As seasonality played a key role in contributing to vulnerability longitudinal monitoring of cage management activity was necessary to assess if cage operators showed seasonal variation in their activities. The number of fish stocked and harvested was monitored concurrently over the same time-scale as fish catch and household livelihood parameters. The methods detailed below were initially tested with farmers in USG village and were reviewed prior to use in the intervention at RAJ.

In addition to regular discussions with cage operators the principal means of monitoring cage operator behaviour was through a monitoring questionnaire designed to quantify inputs and outputs and account for seasonality. After field-testing the questionnaire for cage operators was implemented concurrently with the household livelihoods questionnaire between June 2001- May 2002 in USG village and October 2001 – May 2002 in RAJ. As the researchers could not be present each

[1] Specific growth rate (SGR) is defined as ln Wt 2 - ln Wt 1 / No. of days x 100

time a cage operator stocked, fed or harvested fish from their cage, much information gathered about cage management was based on participant recall. In addition to this, the cage operators maintained notebooks with the date, number of fish stocked and length at stocking. The book was viewed as a "bank book" amongst cage operators, helping them to monitor the number of fish in their cage. This additional record keeping was encouraged to facilitate crosschecking of information gathered through the questionnaire.

Cage stocking frequency

An examination of cage stocking patterns was achieved using data from operator notebooks, cross-checked with data from the cage operator monitoring questionnaire. The stocking patterns were of particular importance to assess if cages were stocked when there was an abundance of small tilapia or if they were stocked even when the relative availability of small tilapia was low. This was viewed as indicative of whether cage culture was used by the operator as a constant means of 'saving' or if use was only stimulated by high availability of small tilapia. The analysis focused on determining the numbers of small fish stocked in each operators' cages across the monitoring period and then established if there was a significant statistical relationship between stocking and household income from fishing. The opportunity cost of stocking small tilapia was examined by determining the percentage of total catch value accounted for by small tilapia and establishing if there was a relationship between their importance to household income and the numbers stocked.

Harvesting data

The main constraint to collecting accurate harvesting data was that cage operators harvested fish according to their requirements. As the monitoring frequency was fortnightly researchers were not present each time harvesting occurred. Therefore harvesting data relied on participant recall and was recorded by participants in their cage notebooks. The records showed the date of harvest, number of kilograms harvested and which size category and price they fetched. The reasons for harvesting the cage were also examined during the questionnaire and were recorded by the enumerator. Unanticipated events such as cage damage, repairs and incidences of poaching were also recorded during the interview. In some cases the participant announced harvesting in advance. This allowed the research team to weigh and measure fish upon harvest and to observe sales firsthand.

A key hypothesis was that cage culture could reduce household vulnerability when household income from fishing was low. This was tested by monitoring the household income expressed as income from fishing (Rs./day) for each month stated. The biomass of fish harvested from operator's cages in each month was also monitored in the cage operator questionnaire and was crosschecked with information from the cage operator notebooks.

Feed sampling methodology

To investigate performance and indicate the success of the diets used by participants, feed samples were taken. Dietary composition in both USG and RAJ villages was varied in its ingredients with a variety of household food waste, rice bran or polish and fresh fish and fish viscera often cited by participants as ingredients used. To provide a brief indication of the impact of these ingredients on the resultant feed quality, feed samples were collected once every month from operators during periods in which cages were in operation. Moisture content was assessed using standard methods. Dried samples were stored in containers with silica gel desiccant and taken back to the U.K. for laboratory analysis of crude protein, crude lipid and ash content using standard methods (Nielsen, 2003).

Constraints to monitoring farmer input to cages

The choice of whether to land fish or stock them in the cages was made by fishers. Subsequent monitoring followed up the decision-making process that was regarded as an important part of the research. Once fish were removed from the gill nets they were held in the bottom of the canoes, which were partially flooded to keep the fish alive until they were stocked in the cages, on the way back to the landing site. On the spot decision making by fishers on whether to stock or land fish meant that monitoring the number and size of fish stocked depended on the fishermen as the stocking patterns of fishers could not be pre-empted. Initially participants agreed to monitor fish inputs (length and number of fish stocked) using rulers distributed to them by the project. However, due to difficulties expressed with measuring fish in boats this gave way to counting of fish rather than making measurements for each individual. After visiting farmers in the early stages of cage operation they decided that measuring the precise size of fish using the ruler was too complicated to manage on the boat and therefore fish were counted with an approximation of size and quantity made by the cage operator. On returning home this information was recorded in the small cage record book with the number and approximate size noted. The sex of the fish was also proposed as a parameter for recording to establish if male fish were preferentially stocked by participants. This was eventually abandoned as it became apparent that some participants were unable to accurately differentiate between the sexes of male and female tilapia and this became more prevalent as some participants were stocking at very small sizes. Despite training, some of the cage operators continued to base their observations of sex on the body colour of the fish. A further constraint was identified in this regard as tilapia changed colour due to handling stress. There was some colour differentiation between individual fish that was possibly accounted for by the some level of hybridisation between species of *O. mossambicus* and *O. niloticus*.

Determining when participants would stock fish was difficult and meant that compromised accuracy of stocking information had to be accepted. Farmer estimates of length were tested against a known lengths measured from the tank population and were consistently found to deviate from their true values by 27.09% in USG and 7.57% in RAJ. The low level of precision in collection of such data meant that utilisation of farmer collected data to calculate basic performance indicators such as FCR and SGR was not attempted. A researcher-managed trial with the specific aim of assessing FCRs and SGRs was initiated to establish baseline data on the technical performance of the cage-based fattening of tilapia system in the absence of this data being derived from the farmer-managed trials. This trial is reported as a separate document (Pollock & Little, 2003).

Consumer Preference and Fish Marketing

Post- harvest consumer preference testing was conducted with cage and tank fish in USG and Galgamuwa and later at RAJ. Consumers were blind tested i.e. not told the origin of the fish and were asked to score them out of a maximum of 5 based on skin appearance and colouration, sliminess, flesh firmness, gill colour and their overall size. In USG only, fish were cooked as a curry and then returned to the same respondents later in the day to ascertain if any differences in taste and texture could be detected. Participants were asked to rank the fish in order of preference rather than score them. When participants cited no difference between fish each was awarded 0.5. Preferred items were ranked as 1.

Alternative uses of cages and feed ingredients.

Alternative uses of cages and feed ingredients were assessed when necessary. These interviews took place with respondents observed using their cage for an alternative purpose. The interviews sought to establish the relative advantages of the alternative use considering economic or other advantages in this respect.

5.3 Results

The results section is separated into two case studies of practices surrounding interventions in USG and RAJ villages as the patterns of events differed in each community. Each case study presented contains an overview of the characteristics of the adoption or rejection of cage-based fattening of tilapia and the specific technical and social experiences of participants of using cages. Village maps are presented for orientation highlighting households within the monitoring group and key village institutions.

5.3.1 Case study – USG village

The village map of USG is presented in Figure 5.1. This map highlights the households and rice mills within the local area and the location of cages within the tank.

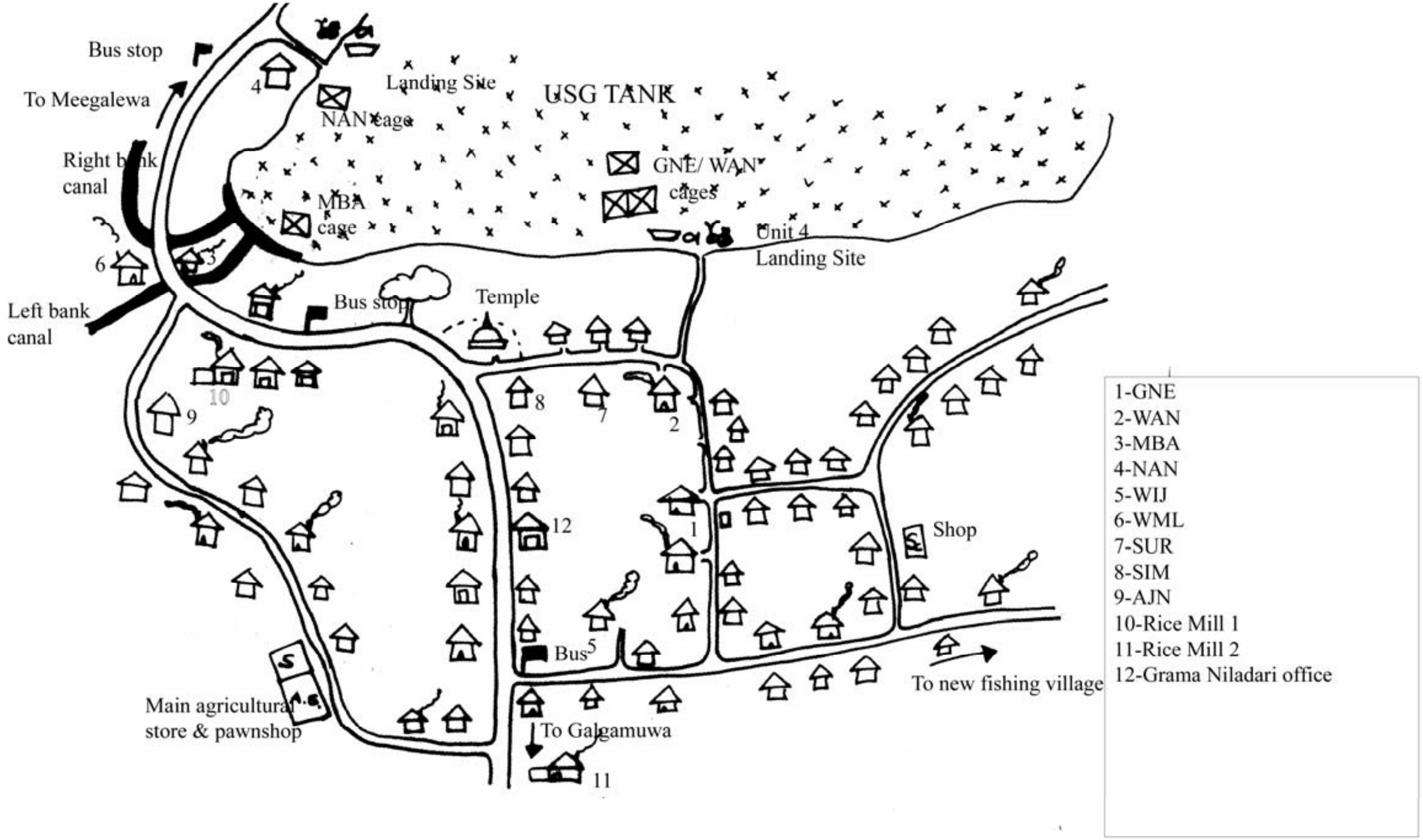

Figure 5.1 USG village map

Adoption of cage culture

The initial intervention in USG village began with 10 male cage operators who were randomly selected from a list of participants that had regularly attended community meetings and had registered their interest. Cages were designed in collaboration with the local community to identify abundant and low cost local materials. Cage materials and construction costs were met by the research project. For constructing the cage frame a local carpenter was employed. It took two men one day to complete each cage. Net bags were fabricated in Galgamuwa town by tailors using a frame around which the net bags could be attached to polyethylene ropes and sewn in place using 8 ply nylon fishing yarn. The net bags were made from knotted fishing mesh of 1 inch stretched mesh. Fishing mesh of this size was normally used for fishing for minor cyprinids in the tank fishery. The cage design and installation is shown in Plate 5.1.

Assistance for cage construction in USG was achieved for speed to start the intervention prior to the onset of the *maha* monsoon. Despite the fabrication by a carpenter the cages could have been constructed using the skills of the fishers as they were simple to construct and required just a machete for bamboo cutting and splitting.

Plate 5.1 Initial bamboo cages with nylon net mesh bag insert

Ten operators installed their cages at USG village in December 2000. Due to requests from other interested villagers a further 4 cages were fabricated with the expense met by the research project, these were installed in March 2001. Two further fisher-farmers made cages fabricated from *ipil ipil* (*Leucaena leucocephala*) that they had collected from jungle areas near to their house. The project provided them with net bags to help them start up. This increased the number of cage operators to 16 by the end of March 2001.

After March 2001 the number of participants operating cages decreased for both technical and social reasons. The operators choosing to stop cage culture were interviewed in April 2001 and asked to indicate the reasons for their discontinuation. Figure 5.2 plots the number of participants operating fish cages over 19 months of field research in USG village. The dwindling importance of cage-based fattening of tilapia to June 2002 is depicted.

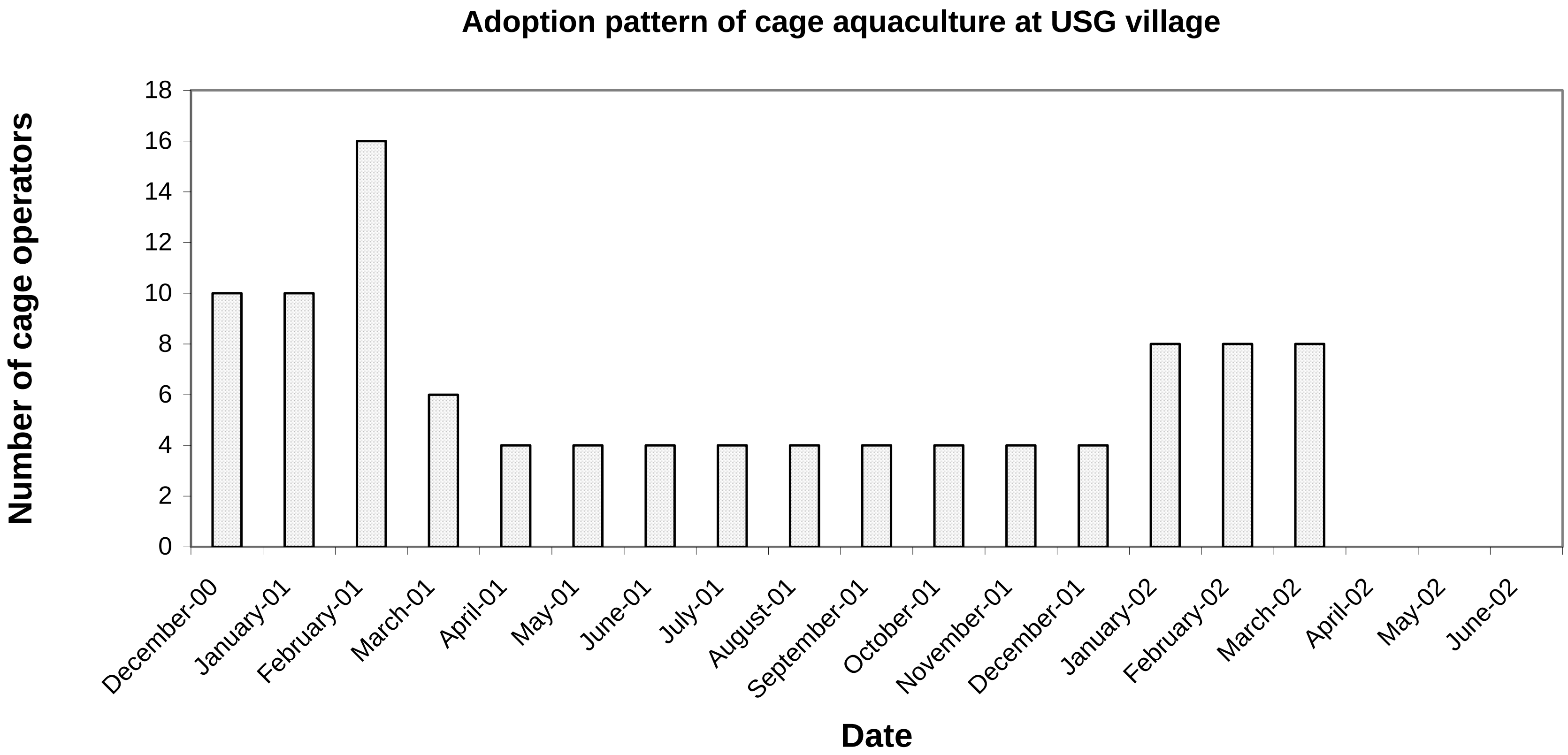

Figure 5.2 Adoption pattern of cage culture at USG

Discontinuance of cage culture

Of the sixteen initial adopters twelve had stopped cage culture by March 2001. Other than the key technical issues highlighted above participants cited other reasons for their discontinuance of cage culture. A scoring exercise was conducted at the beginning of April 2001 with discontinuing operators. Of the twelve discontinuers targeted, eight were located for interview. Three operators had migrated to undertake employment outside the village. The other remaining operator committed suicide at the end of February 2001.

The scores allocated ranged from 5 = very important to 0 = unimportant. The average score allocated for each factor was determined and is presented in Figure 5.3.

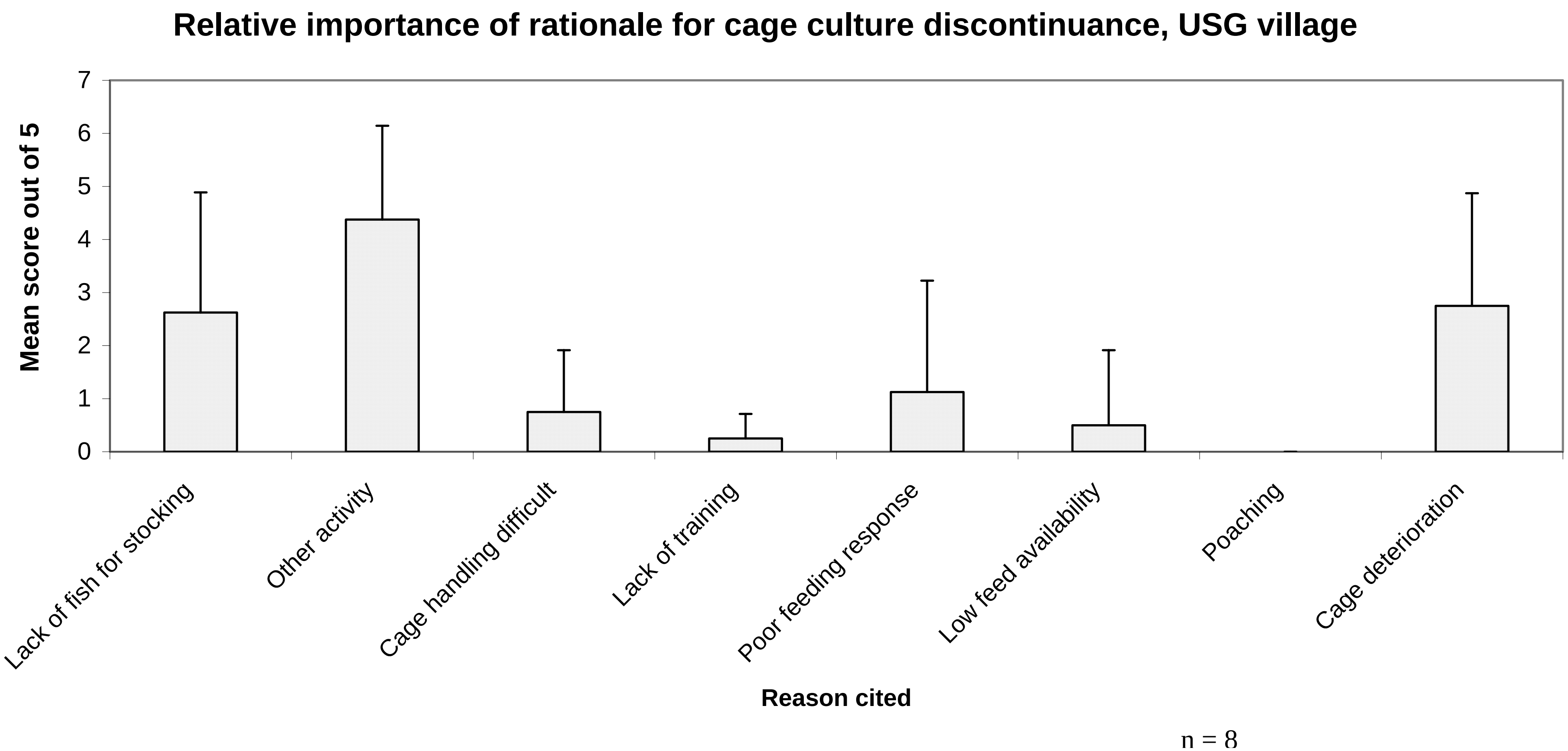

Figure 5.3 Identified constraints to cage culture adoption in the initial six months at USG village

The most important reason for cage culture discontinuance was the participants' involvement in other activities. Three participants indicated that they became involved in construction work at the new fishing village. One participant was working part-time as a barber and attributed greater importance to that activity than the fish cage. Another had applied to join the air force and was preparing to leave for Colombo. A further respondent had reduced his fishing activities to provide childcare and undertake domestic activities since his wife had gone to the Middle East to work as a housemaid. Another participant left the village to produce and sell illegal alcohol (known as *kasipu*) he deemed to have a far better financial return than fishing. His departure was perhaps forced by the hostile response he had received from some villagers as consuming alcohol is often frowned upon.

In addition to other demands on their labour, participants who discontinued cage culture were also discouraged by the technical performance of the cage materials. Furthermore between December 2000 and January 2001 some cages sank resulting in fish loss.

Low fish catches at the time of intervention frustrated cage operators as they found it difficult to catch enough small tilapia to stock in their cages. There were two main causes for the low fish catches. Firstly, water levels in the tank increased in November with the onset of the monsoon season, which normally made catching small tilapia more difficult. Larger fish are sought at this time and are prevalent in the catch. Secondly, the ban on fishing at night was enforced in January 2001. This meant that boats had to be locked up between 6 pm and 6 am although after protest by the fishing society and consultation with the fisheries extension officer this time was revised to 6pm – 5 am. Due to complaints received from some fishers at USG tank about the use of meshes less than 3.5", the fisheries extension officer threatened to confiscate offenders' fishing nets. This caused divisions within the fishing society, principally because the majority of complaints were derived from wealthier fishermen who had complained that their nets were being poached and gears stolen at night. They could also fish using larger meshes (within the law) as they could afford more nets and consequently could derive an income using the fishing resources at their disposal. They had reduced their dependency on fishing for income generation as their wives sent remittances from the Middle East. In contrast poorer fishermen argued that smaller tilapia were all that they could catch in sufficient quantities to support their household income requirements. Despite the arguments for and against the ban, it was implemented and led to decreased catches which was particularly felt by fishers dependent on small tilapia. Murray (2004) monitored the impact of this ban at Galgamuwa junction, a major assembly point for fish derived from USG and RAJ tanks, during an investigation of fish marketing networks. This shows that the volumes of small tilapia rapidly decreased after the initial implementation of the mesh size regulations. However, Figure 5.4 also shows that the impact of the ban was relatively short-lived as small tilapia re-emerged in the catch in April 2001. A perception had emerged amongst fishers that contravention of the laws would not result in prosecution as previous court proceedings for illegal fishing activities had been subverted by the intervention of local politicians.

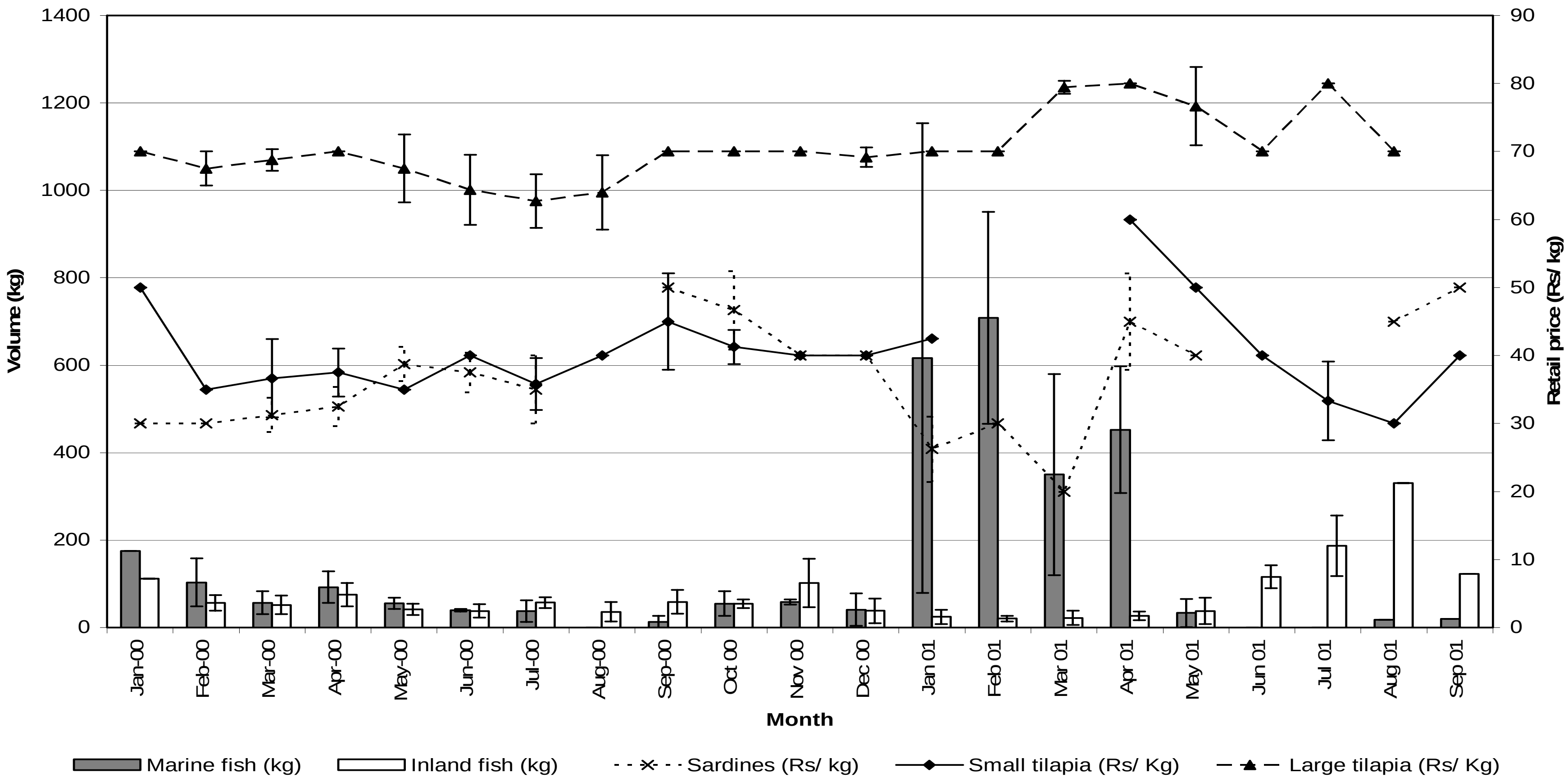

Figure 5.4 Mean total daily volumes for fresh inland and marine fish and mean monthly retail prices for selected varieties in Galgamuwa town NWP 2000-2001 *Source*: (Murray, 2004)

Poaching was not considered a reason for discontinuance. Cage poaching however had occurred in the initial stages although this had only happened to those who continued cage culture. Although they were disheartened by this experience they restocked and continued cage operation.

Despite the problems experienced with the initial cage designs and the timing of implementation against a background of low fish catches and fishing society unease, four cage operators decided to continue their participation and agreed to be monitored for the forthcoming year. As part of the household livelihood and cage operator monitoring process their cage operation activities were monitored between June 2001 and June 2002.

Technical constraints

Technical constraints were identified as one factor contributing to discontinuance amongst initial operators in USG. A workshop held with these remaining participants in June 2001 reviewed cage design and new cages designs were implemented addressing the issues stated in Table 5.1. The new cages fabricated from iron bar frames and galvanised metal mesh (Plate 5.2) were introduced over the monitoring period and were found to have a useful working life of approximately 6 months in freshwater before they succumbed to corrosion. After the cage design had been tested by other participants a renewed interest in cage-based fattening amongst fishers from the newly constructed fishing village was noted from January to March 2002. This decision to re-adopt the technology was driven by the positive experiences of others and also by the increased availability of time after building work in many of the homesteads was complete. This revival of interest, however, was short-lived and cage-based fattening ceased amongst all participants in March 2002. When interviewed about their rationale for discontinuance, new participants cited their difficulties obtaining enough small tilapia to stock their cages. However, some participants still thought the concept of cage-based fattening of tilapia was valid. This may suggest that with further technical modifications to the system and any future increase in the availability of small tilapia, the system may have a role.

Table 5.1 Identified technical constraints to cage operation using bamboo cage design in USG village.

Constraint	**Evidence**
Cage materials and design	Split bamboo attached to prevent damage to the mesh bag by predators had a short working life of 4 months in water. This was weakened by predators and provided less resistance to opportunistic poaching. Coir ropes used for fastening split bamboo pieces to the outside of the cage were less resistant to the aquatic environment and loosened, weakening the cage structure. Large bamboo pieces comprising the main part of the cage frame had a longer working life and their use continued.
Anchorage	2cm diameter coir ropes were used to attach the anchor to the cage. As tank water levels rose rapidly during the monsoon season, the breaking strain of the rope was exceeded before cages could be relocated in shallower water and consequently some operators' anchors snapped. These cages drifted into the tank, but were later retrieved.
Floatation	Locally available kapok (*Ceiba pentandra*) logs lost their buoyancy after approximately two months. In instances where cages sank, fish were lost.
Competition and predation	Minor cyprinids such as *Amblypharyngodon spp. Rasbora spp*. and *Puntius spp*. attracted to the cage by feeds were caught in the net mesh bags causing fouling. Monitor lizards and otters damaged cages in attempts to catch the trapped fish and those within the cage. The bamboo splits were not strong enough to repel this threat.
Security	Some poaching had occurred preceding the Singhalese New Year. Fish were easier to access since cages could be easily broken as the split bamboo covering began to degrade and net bags could be lifted enabling the fish to be stolen.

Plate 5.2 Cage design using galvanised metal mesh.

The initial experience with bamboo cages highlights the problems of making a technical trade-off between durability and cost. Some participants reported that they could no longer rely on the cage materials and would not participate until the system had been technically proven. This failure of the bamboo cage design to meet the expectations of many cage operators meant that alternative cage materials had to be sought before more widespread adoption could be expected.

Stocking and harvesting patterns

The main hypothesis was that income from sale of cage-fattened tilapia could mitigate seasonal fluctuations in household income from fishing. Therefore, it was important to understand operators' stocking and harvesting patterns and the contribution of cage culture to the household for any impact on vulnerability caused by seasonality to be determined.

5.3.2 Stocking in practice

In the initial stages of the pilot trial cage operators experienced high mortalities amongst stocked fish. This arose through inexperience of handling live fish. During subsequent second cycles of cage stocking mortalities were lower which cage operators attributed to greater experience. The cage operators collected fish from the gill nets and stored them in the flooded bottom of their canoes until they reached the cage en route to the landing site. After discussions with participants a number of constraints to this method were identified. Their choice of fish for stocking relied principally on whether the fish were dead or alive by the time they reached the cage. Fish once caught could remain in the gill nets for up to 14 hours as fish caught early in the evening fishing session were typically dead or moribund when the nets were checked in the morning. When fish were removed from the nets there was some concern that their gills and scales were damaged as they were pushed out of the nets. Once aware of this problem, and its relationship to post-stocking mortalities had been established, cage operators reviewed their practices. Subsequently the liveliest fish, caught later in the fishing period, were handled with greater care and preferentially stocked. GNE reported that he sometimes fished solely for fish with which to stock his cage. This was normally conducted in the daytime with gill nets being lifted shortly after setting down to reduce the time fish spent in the nets consequently maintaining the quality of fish for stocking.

Up to four cages were operated by one operator with his neighbour operating two cages. The two remaining cage operators maintained one cage each over the monitoring period.

Data was disaggregated to show variation between each operator. Average values of the actual quantities of small tilapia caught (kg/boat/day) based on the data collected on the day of interview and the day before were used in the analysis. Two monitoring rounds per month were conducted and the values of fish catch were subsequently averaged for each month. The total number of fish stocked was calculated from data recorded in farmer notebooks and from participant recall during the cage operator-monitoring questionnaire. The results of the correlation analysis are shown in Table 5.2. Statistical analyses are presented in Appendix 5.

Table 5.2. Results of correlation analysis of average actual catch of small tilapia (kg/boat/day) and number of fish stocked in cages.

Operator Name	Pearson Correlation r =	Sig. of *p*	n
GNE	0.133	0.680	12
WAN	-0.023	0.944	12
MBA	-0.018	0.955	12
NAN	0.120	0.711	12

These results indicate that there is no significant relationship between the average catch of small tilapia and the numbers of fish stocked each month. This could indicate that participants had an entirely random approach to stocking, perhaps stocking when they had small fish excess to their requirements for immediate consumption or sale.

The opportunity costs of stocking small tilapia rather than selling them were also analysed. This was achieved by calculating the percentage contribution of small tilapia to the total income from fishing. This variable indicated the relatively high importance of small tilapia to overall income from fishing. The hypothesis tested was that when small tilapia accounted for the greatest percentage of income from fishing, that stocking would not occur. That is to say that if household income from fishing is more dependent on small tilapia, landing and selling them is more important that stocking. This approach indicated the extent to which the household was dependent on the income from small tilapia rather than medium or large tilapia size categories.

Pearson correlation analysis was conducted to identify whether there was any relationship between contribution of small tilapia to the total household income from fishing (%) and the average number of fish stocked in the cage per month. This was disaggregated for each cage operator. Results of the analyses are presented in Table 5.3. Statistical analyses are presented in Appendix 6.

Table 5.3 Results of correlation analysis between relative financial contribution of small tilapia to the total catch (%) and total number of fish stocked in the cages per month.

Operator Name	Pearson Correlation r =	Sig. of *p*	n
GNE	-0.358	0.253	12
WAN	0.213	0.507	12
MBA	0.226	0.479	12
NAN	0.022	0.946	12

The analysis indicates that there was no significant relationship between average percentage contribution of small tilapia to income from fishing and the number of fish stocked in the cages each month. This outcome reflects the findings of the previous analysis and suggests similar reasons may contribute to this behaviour.

This could be indicative of a completely random pattern of stocking behaviour, but since it was not possible to collect fish catch data on the same date as fish were stocked in the cages, the validity of the analysis to determine stocking behaviour is questionable due to the daily variation in fish catches and concomitant contributions to household incomes. Participants may also stock their cages as an *ex-ante*[1] strategy. During household monitoring interviews all participants cited that they wanted to reach the maximum stocking density (200 fish/ m^3) indicating that the cage would be used as some form of *ex-ante* livelihood risk management strategy through their forward planning. The evidence suggests that stocking was not related to either availability or opportunity cost of small tilapia in the catch. This indicated that there might be other livelihood or personality variables determining cage management behaviour other than availability of fish to stock. There is also a possibility that operators may have stocked their cage to please the researchers rather than for their individual needs.

Without monitoring fish catch and stocking activity on a daily basis it is impossible to conclusively determine if the catch of small tilapia, or its contribution to the overall catch or income from fishing, played key roles in stimulating or constraining stocking.

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[1] Ex – ante action is a forward looking strategy, taken in this case to mitigate anticipated reductions in future income.

Farmer feed formulations

Samples of farmer – made feed were collected once per month from cage operators between November 2001 and March 2002. The samples were dried and taken back to the U.K. for proximate composition analysis.

Table 5.4 indicates that cage operators used feed which was very high in moisture content and far lower in protein than the recommended diet. Of critical importance is the relative protein content. The farmer made feed consisted of variable, but overall low, levels of protein when compared with the researcher recommended diet. The degree of variability in the farmer-made feed was accounted for by the difference in ingredients used on a day-to-day basis and between operators. In many instances farmers substituted household food waste such as rice and vegetable matter for fish which may account for the high moisture and low protein composition of the diet.

Table 5.4 Proximate composition of farmer-made feeds in USG village

Participant Name		Moisture	Ash	Lipid	Protein[1]	n
GNE	Mean	65.9	15.9	7.5	10.2	5
	St. Dev	5.4	3.0	2.3	4.5	
WAN	Mean	64.3	16.1	6.1	7.8	5
	St. Dev	5.1	4.9	1.6	1.4	
MBA	Mean	66.5	17.0	6.8	13.5	5
	St. Dev	2.7	1.7	1.4	7.3	
NAN	Mean	59.8	11.3	6.6	9.7	5
	St. Dev	4.5	7.9	3.8	3.5	
Farmer-feed	Mean	64.12	15.27	6.78	10.3	20
	St. Dev	4.99	4.79	2.09	4.79	20
Researcher – recommended feed	Mean	27.68	11.87	21.26	23.71	4
	St. Dev	5.51	1.18	2.33	0.75	

One cage operator stated that he did not add fish to the feed until there were over 50 fish in his cage. It was at this threshold that he deemed the return on labour of feed preparation and administration acceptable. Two cage operators also expressed some discomfort with feeding fish to fish, however, this was not raised as a constraint to feeding practice during community meetings prior to the intervention.

[1] Data for ash, lipid and protein content presented on a dry matter basis.

Some participants did not sieve rice bran in order to limit their feed preparation time. The results of a proximate composition analysis on sieved and unsieved rice bran are presented in Table 5.5.

Table 5.5 Proximate composition of rice bran reflecting quality differences achieved by sieving

Rice bran type		Moisture (%)	Ash (%)	Lipid (%)	Protein (%)	n
Seived	Mean	11.63	11	7.08	6.55	3
	St. Dev.	-	0.026	0.06	0.05	
Unseived	Mean	10.2	14.67	13.37	4.93	3
	St. Dev.	-	0.03	0.52	0.186	

These results indicated that the overall quality of rice bran that has been sieved was higher, therefore concluding that sieving rice bran to remove husk is one active step that farmers could take to improve feed quality. The ash content of unsieved rice bran is higher than the sieved sample.

Day to day availability of feed ingredients contributed to deviations in feed quality rather than an overriding seasonal effect.

5.3.3 Harvesting strategies

The number of fish available for stocking was cited as a constraint contributing to cage operator discontinuance in the initial stages. Monitoring the exact numbers of fish in cages was problematic. Firstly, stocking data collected by participants was the only information source on the numbers stocked available and secondly, the outputs of fish from the cages were recorded as weight in kilograms harvested rather than counting the individual number of fish. Recording harvesting details in kilograms prevented excessive handling of the fish, which could damage their market appearance. Weighing fish rather than counting and weighing also reduced transaction time at the side of the tank which kept vendors on schedule. Another difficulty of ascertaining cage productivity was the tendency for cages to be partially harvested. One cage operator exhibited this strategy and harvested his cages in response to requests from vendors and neighbours in order to meet short-term income shortfalls.

It was hypothesised that fish cages would be harvested to reduce household vulnerability caused by short-term decreases in income from fishing. Household income from fishing was used as a best proxy for total household income. This was because day–to-day household income was more influenced by the daily cash income of fishing than any other income source. Taking this approach to indicate if short-term income reductions in the income from fishing were influential in determining participant harvesting behaviour a further Pearson’s correlation analysis was undertaken. The results of a correlation analysis between monthly household income from fishing and the number of kilograms of fish harvested from cages are presented in Table 5.6. The details of the analysis are presented in Appendix 7.

Table 5.6 Results of correlation analysis between average household income from fishing (Rs./day) in each month and the total number of fish harvested (kg/month).

Operator Name	Pearson Correlation r =	Sig. at 2-tailed level	n
GNE	-0.173	0.611	12
WAN	0.327	0.300	12
MBA	-0.271	0.395	12
NAN	0.101	0.755	12

The results indicate that there is no statistical relationship between the income from fishing and cage harvesting and perhaps confirms that revenue from cage culture is not enough to supplement anything more than very short-term losses in income. Factors such as short term demands on household expenditure (not explicitly picked up by household monitoring due to the fortnightly interviewing frequency (Chapter 6) may have been more influential in operators' day-to-day decision making.

To augment the information on participant rationale for harvesting, participants were also asked to cite their reasons for conducting harvests. This is presented in Figure 5.5. This contrasting account of participant rationale for harvesting demonstrated that although the quantitative analysis reveals little correlation between household income shortfalls and rationale for cage harvest, the qualitative approach reveals that cages were harvested to meet shortfalls in income levels. This finding highlights the pitfalls of conducting quantitative survey analysis to indicate household livelihood strategies as decisions are perhaps made on daily assessment of needs rather than chronic shortages of income. Qualitative investigation provides a complementary assessment and can detect these strategies when they are not supported by the quantitative analysis.

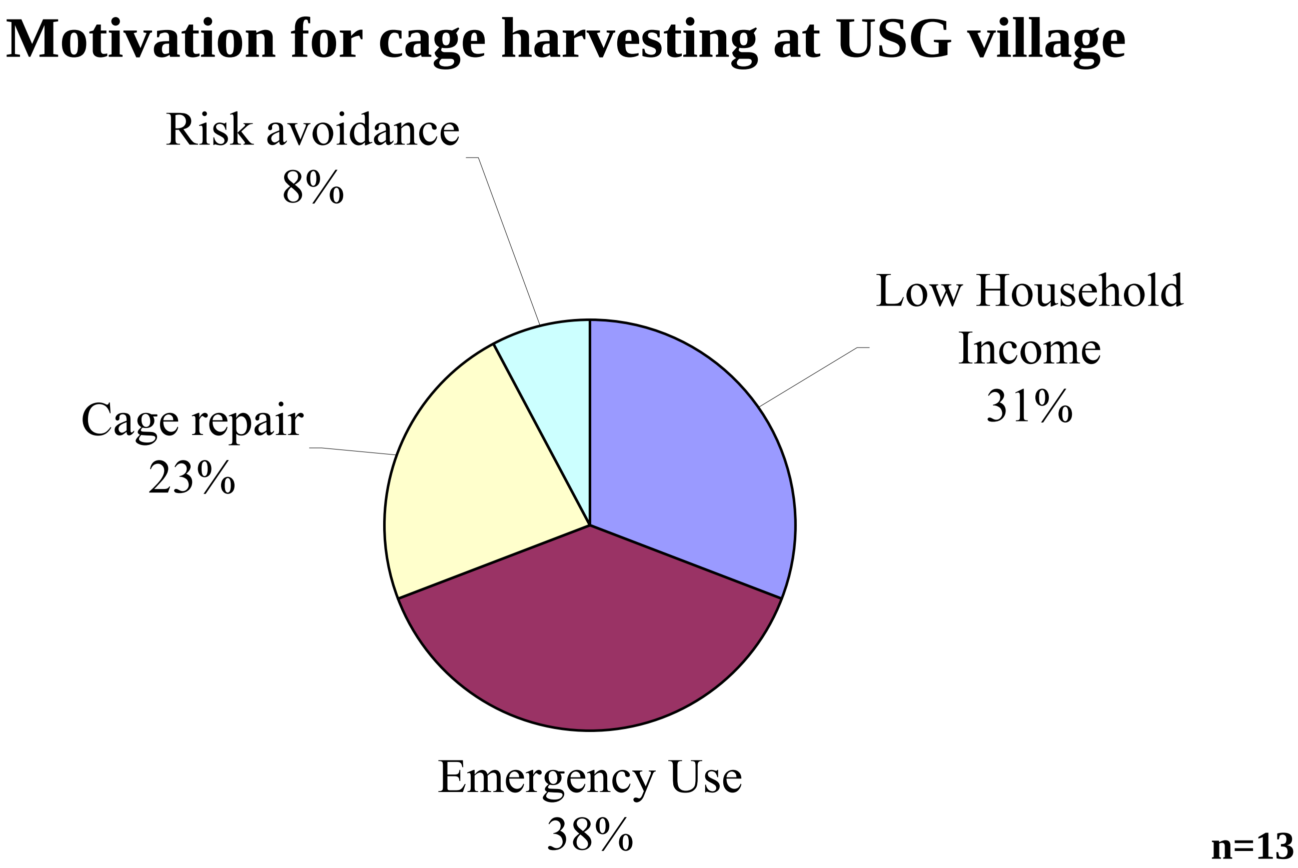

Figure 5.5 Rationale for cage harvesting at USG village

The qualitative evidence suggests several reasons for cage harvesting some of which were outwith the control of the operator. The requirement for cage repairs determined the harvest for some cage operators, who chose to remove the cage from the water entirely before the cage deteriorated to a point where risk from fish escape was a factor, this strategy accounted for 23% of the harvests. Festival and medical expenses contributed to increasing household expenditure requirements. The cage harvest for medical expenses demonstrates that having a stock of fish on which to draw can contribute to provision of additional cash for emergency expenditure and is indicative that the cage held some value for reducing household vulnerability even when the contribution to overall household income from the cage is small. One cage operator used the income from his fish cage to settle a loan (which may be regarded as increased household expenditure). He borrowed money for agricultural inputs and the income from the fish cage contributed to repayment. One operator harvested in February 2002, declared that he had harvested his cage due to the imminent threat of poaching preceding the Singhalese New Year when household expenditure requirements are higher and the temptation to poach fish is greater.

All cage operators in USG had ceased cage-based fattening of tilapia by March 2002. Some cages required repair but most fishers indicated that they stopped due to the shortage of small tilapia in the catch which they could allocate for stocking. Further investigation of the fishery both in terms of its role for provision of seed for aquaculture and as an alternative source of income and market competition is presented Chapter 6.

5.3.4 Cage aquaculture as an income generating activity

Cage fattened tilapia were not a significant source of income for operators. Earnings from the fish cages represented a maximum of 2.27% and minimum of 0.61% (mean 1.16%, St. Dev. = 0.76, n=4) of total annual income. These calculations were based on total household cash income, disregarding paddy production as this was mainly consumed by the household. If paddy production was taken into consideration, the contribution of cage aquaculture would be smaller in relative terms.

These results indicate that cage-based fattening of tilapia plays a marginal role as a household income generating activity and is certainly not a viable alternative to fishing. Some farmers perceived a need to scale-up cage operation activities (GNE, operated 4 cages and WAN 2 cages at some points) however, they were constrained from sustaining this level of operation due to the lack of fish which they could allocate to stocking.

When questioned, all respondents felt that the cage was an additional source of fish should they ever require cash quickly. This indicates that keeping fish was viewed as a useful liquid asset which could be drawn upon in times of need. Comparisons can perhaps be drawn with keeping livestock in this respect.

Fate of fish harvested

The fate of fish after harvesting is presented in Table 5.7. The majority of fish were sold. Only one operator sold or gifted fish to his neighbours. This is likely to be attributed to his ownership of several fish cages and consequently greater quantities of fish compared to other cage operators. There was little household consumption of cage fish. Perhaps because fish were retained from daily fishing for household consumption cage operators attributed higher value to the sale of fish from their cages. Operators were always offered Rs. 35-40/kg irrespective of fish size, which may have been an incentive for sale.

Table 5.7 Fate of fish harvested, USG village

Operator	Total harvested (kg)	Sold to vendors (kg)	Sold to neighbours (kg)	Gifted to neighbours (kg)	Consumed in household (kg)	Max. no. of cages operated
GNE	80.5	70.5	7	1	2	4
WAN	17	17	0	0	0	2
NAN	17	17	0	0	0	1
MBA	22.5	22.5	0	0	0	1

Consumer preference of cage and tank tilapia

The consumer acceptability of fish derived from the cage system was crucial to the sustainability of cage-based fattening of tilapia. This was of particular importance as cage fish were principally sold to vendors.

After harvest cage-fattened tilapia slowly turned black over a period of about 10 seconds. Consumers at USG scored tank fish higher than the cage fish largely because the latter were darker and slimy. All of the respondents at USG reported that they preferred white coloured fish with less slime. Even when newly harvested fish were placed in a white box, the light background only appeared to postpone the colour change to black. In contrast, consumers in Galgamuwa considered the colour of cage fish to be better than those of the tank but were discouraged by the sliminess, which was scored negatively. The preference scoring results are presented in Figure 5.7 and Figure 5.8 after cooking.

After cooking in a curry the respondents agreed that with the exception of one respondent in Galgamuwa, there was largely no taste difference between the two types of fish. The texture of the tank fish was preferred over cage fish as cage fish was firmer. One respondent in Galgamuwa felt that firmer flesh after cooking would be a useful trait for hotel cooks as fish was less likely to break up and result in waste when cooked.

The findings of the consumer preference scoring exercise in Figure 5.6 indicated that the consumer preference for tank - derived tilapia over cage-fattened tilapia represented a considerable constraint to the marketability of the produce and consequently the viability of the system as a consumer – led livelihood activity.

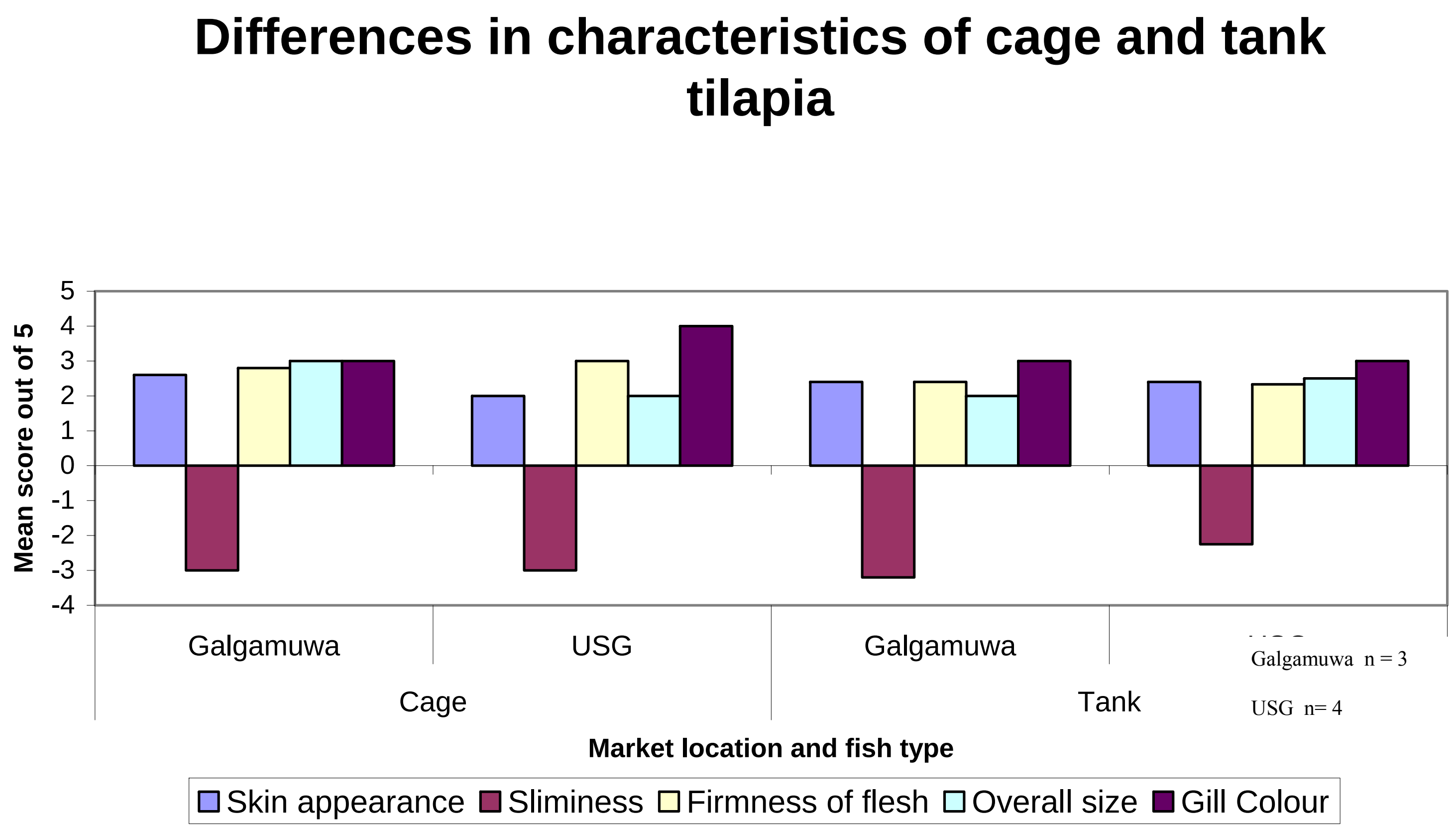

Figure 5.6 Marketing characteristics of cage fish produced USG with consumers in USG village and at Galgamuwa junction

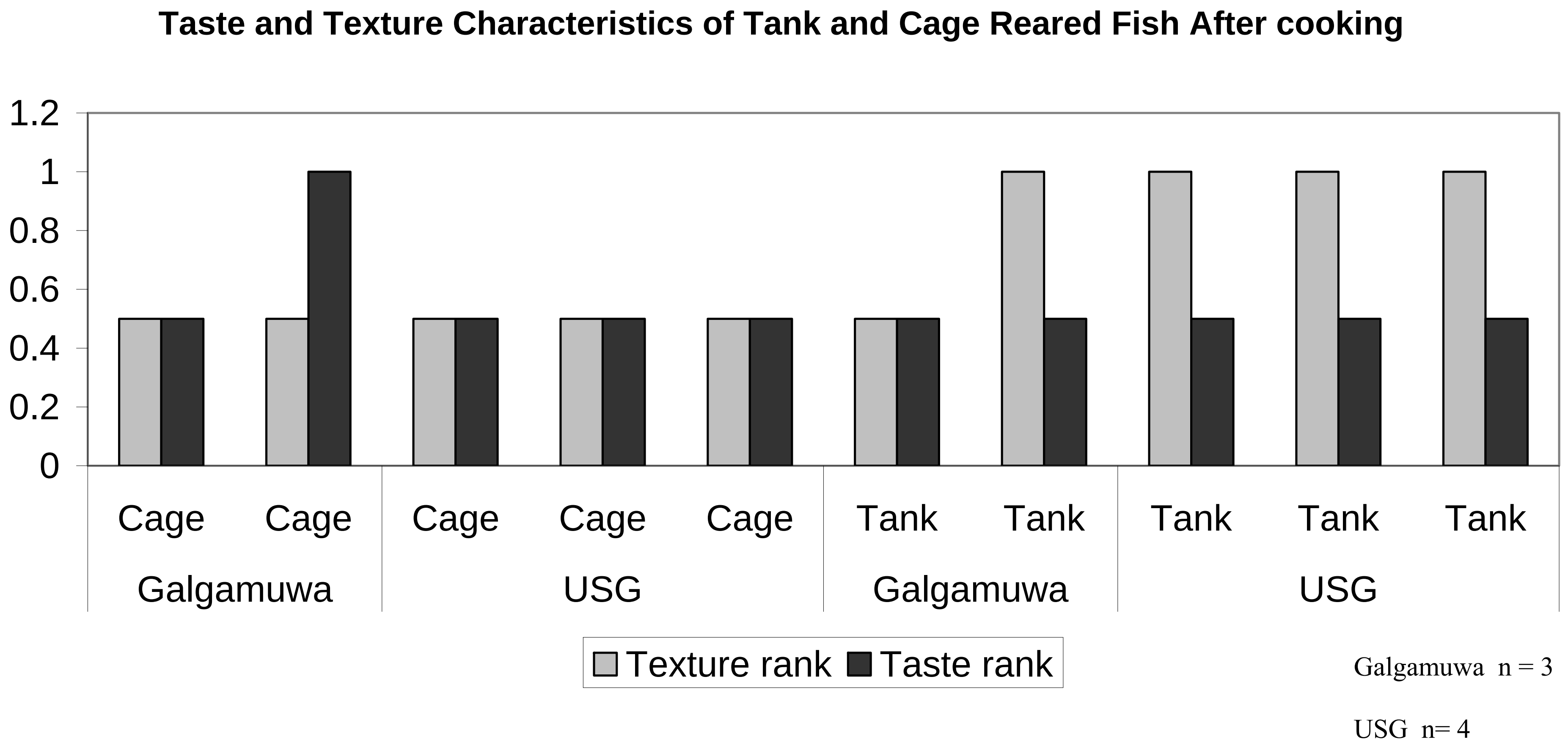

Figure 5.7 Taste and texture characteristic of cage and tank fish after cooking as curry.

5.3.5 Case study – RAJ village

The village map is presented in Figure 5.8. This map highlights the households and rice mills within the local area and the location of cages within the tank

Cage culture was initiated in RAJ village after a series of community meetings. Cage materials were distributed to twelve male and twelve female operators from different households within the village. Participants undertook cage fabrication themselves. The women's group took the lead in this process, the majority of whom completed their cage fabrication ahead of the men. In the few weeks following the intervention, monitoring work around the village revealed that many cages had been fabricated but had not been installed in the tank. The following case study provides a contrasting case study to that of USG village, as it is within a predominantly Christian community at RAJ.

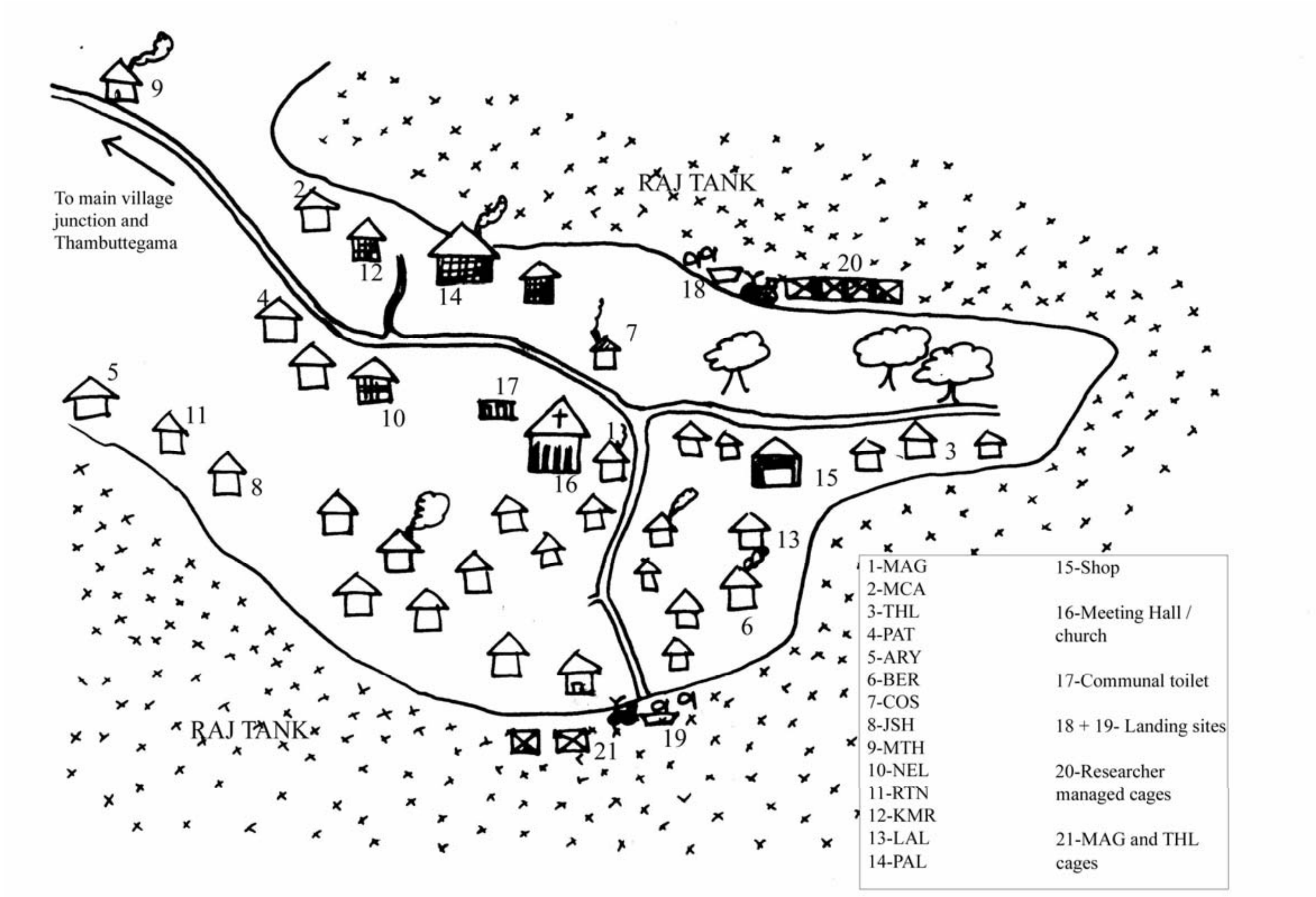

Figure 5.8 Map of RAJ village

Adoption of cage culture

The maximum number of cage operators was recorded in September 2001. At this stage 12 out of 24 cage operators had installed their cages in the tank but only eleven cage operators had attempted stocking. After installation most participating cage operators collected fish for stocking using cast nets. This kept the fish in better condition than gill netting prior to stocking. Weather conditions deteriorated shortly after the cages were installed and fish stocked. Consequently, fish mortalities were very high; in most cases all of the stocked fish died over a period of days. This was largely attributed to the windy conditions creating waves which, in the closed environment of the cages, caused the fish to lose scales and suffer skin abrasions that resulted in mortalities. The majority of these operators did not restock. Consequently, the numbers of people operating cages gradually declined from October 2001 to March 2002. In Figure 5.9 the activities of the two remaining cage operators were subsequently monitored.

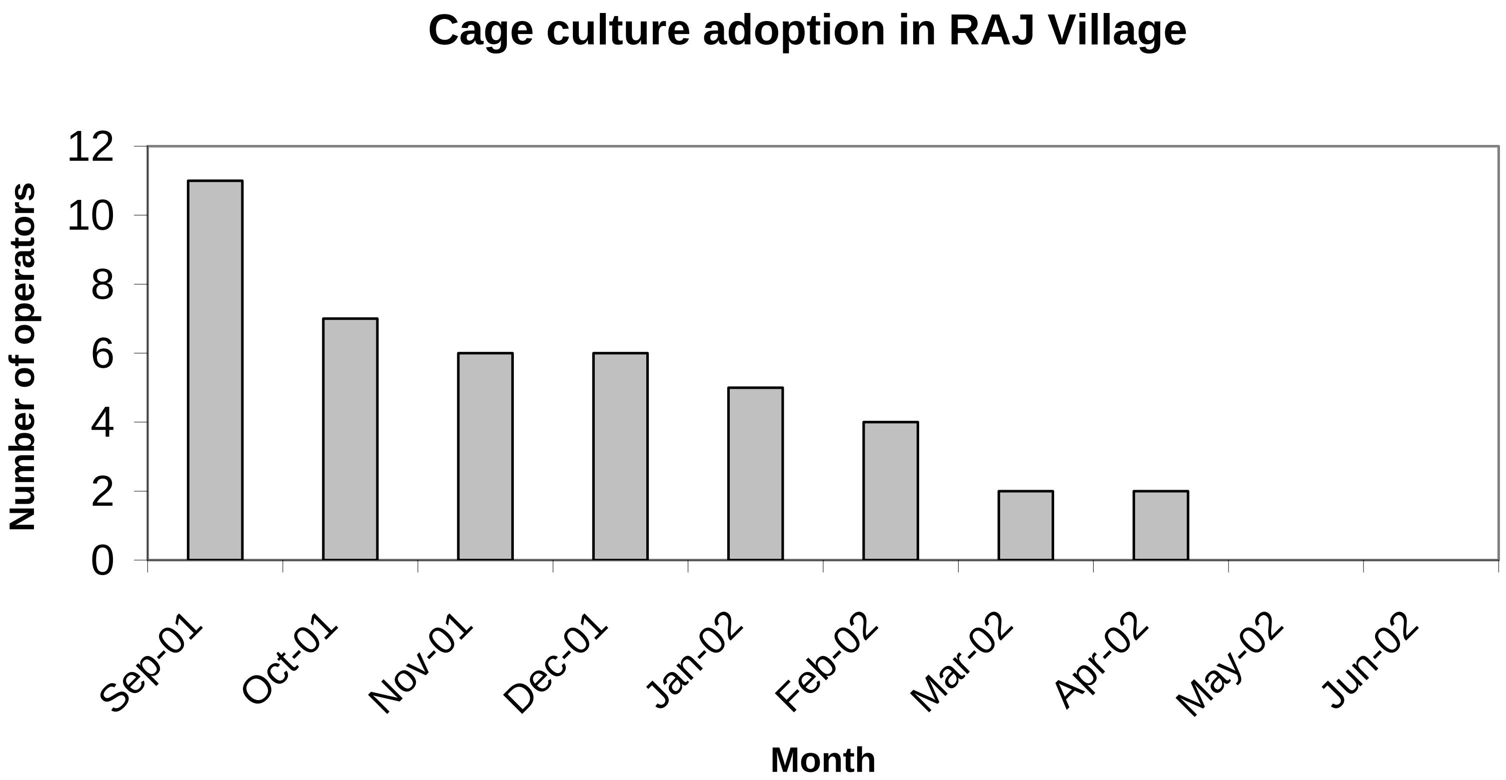

Figure 5.9 Adoption of cage culture in RAJ village

After this phase a survey was taken around the village to establish why some operators had not installed their fish cage. The survey revealed varying progress in participant attempts to undertake cage-based fattening of tilapia. This is depicted in

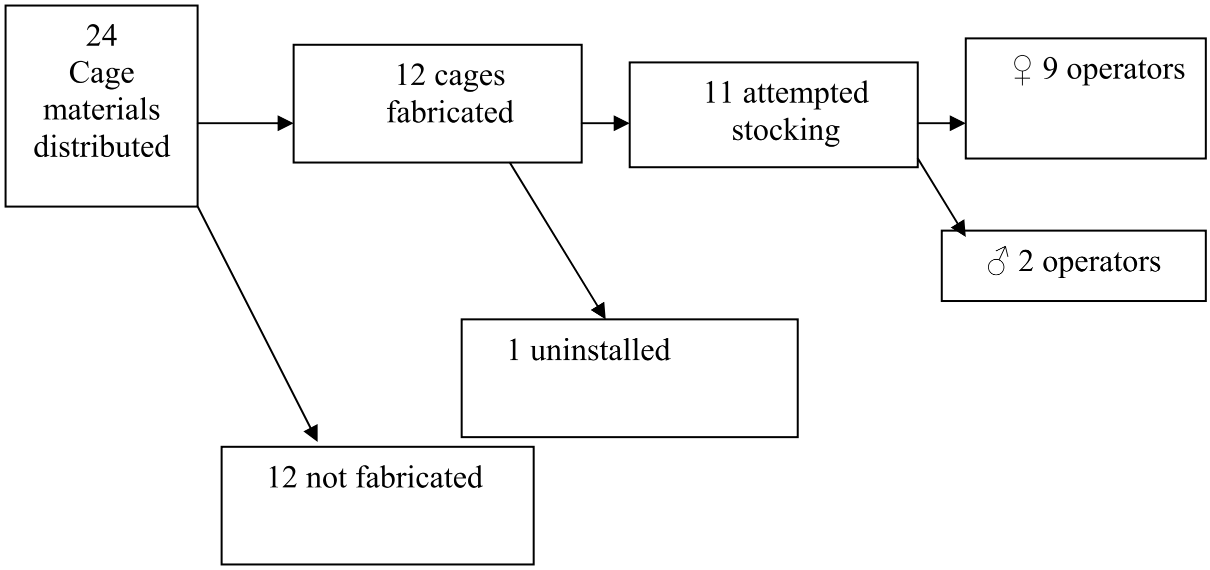

Figure 5.10 Fate of distributed cage materials, RAJ village.

Interviews to assess reasons for not installing cages or discontinuance of cage culture revealed varying problems. The experiences of male and female operators were markedly different. The reasons cited for discontinuance or unwillingness (in percentage of respondents citing them) to start cage operation is depicted in Figure 5.11. The findings are disaggregated by gender.

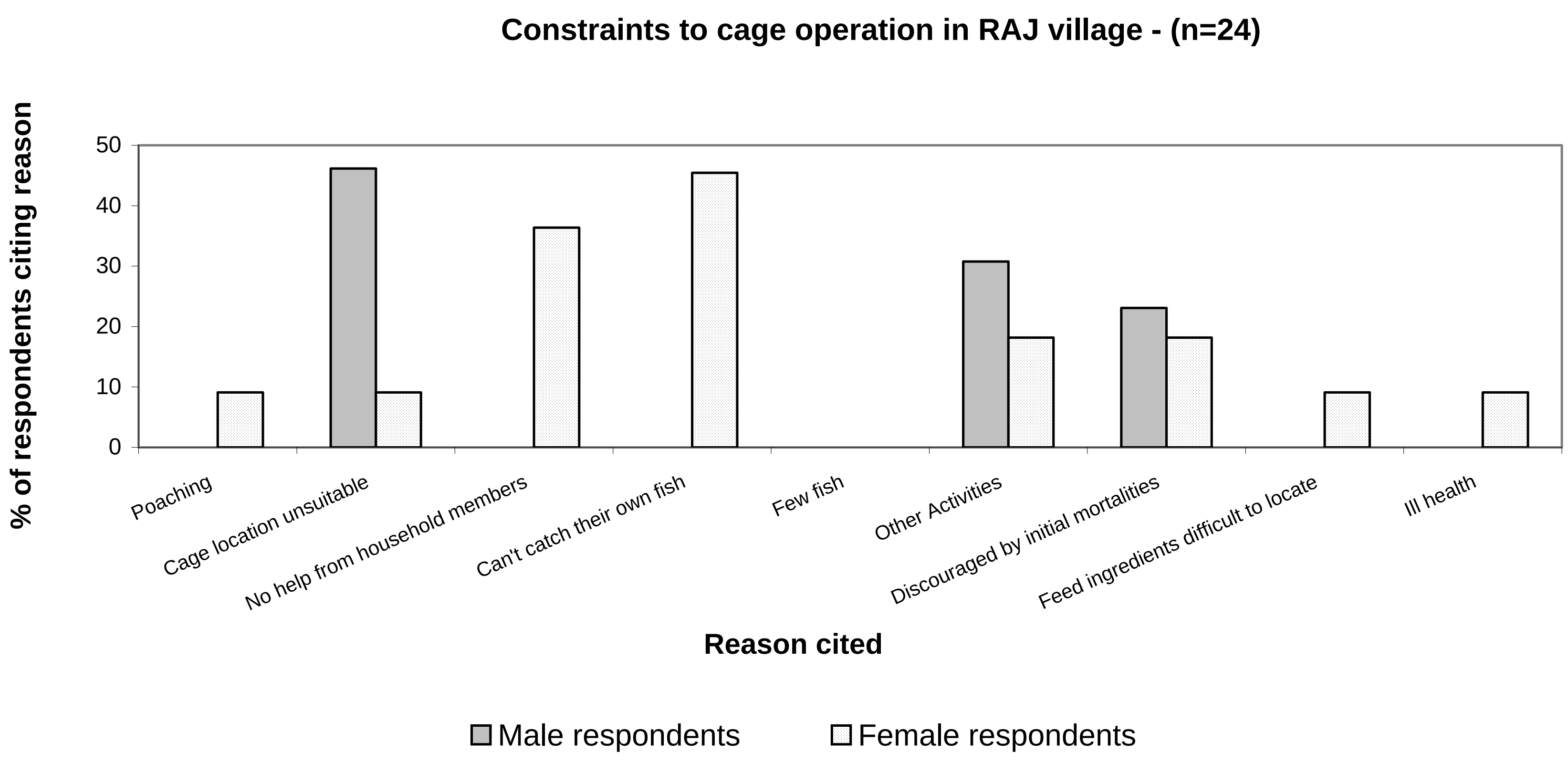

Figure 5.11 Constraints to cage culture adoption RAJ village

The most frequently cited reason for failing to starting cage culture was the unsuitability of the cage location. The cages could be installed at either side of the peninsula on which the village was situated. Those with homes on the perimeter of the village were reluctant to install cages when they were up to 100 metres from their homesteads for security reasons and stated that they would construct and install their cages as the water level increased. Most of the men interviewed were reluctant to attempt cage culture until the water level of the tank had increased to a level where a cage could be installed a short distance from their household. Involvement in other activities such as fishing and childcare was also an important constraint for men. In cases where childcare was mentioned this is due to their spouse working in the Middle East. Initial high mortalities caused by poor weather conditions negatively influenced their decision to construct and begin cage operation. Those who stated intent to fabricate and install their cages were monitored over the following months although their situation did not change. This perhaps indicated that other key features played a central role in determining a participant's decision to adopt. Chapter 6 deals explicitly with these issues at the household level when livelihoods are examined in greater detail.

Despite their physical ability to operate cages women experienced different constraints to those reported by men. These principally related to access to resources. Two large and related constraints were identified when the intervention was underway. Firstly, 45% of women reported that they were unable to catch their own fish for stocking. This was mainly due to the fact that women rarely go fishing alone, usually only with their husbands. Secondly, 36% of women (irrespective of the household head's gender) reported that their family members (mainly referring to sons or husbands) would not help them to stock their cages hence their discontinuance. Consequently stocking activity for female cage operators depended on intermittent cast netting undertaken by relatives or friends. Discouragement by the initial mortalities experienced was also a factor identified by 18% of women. This may have contributed to relative's reluctance to invest fish or fishing time in cage stocking. Some female respondents cited other activities such as home construction as a constraint to activities. 9% of female respondents reported difficulties with obtaining feed ingredients. This was considered a relatively minor limitation in December 2001, but grew in importance to cage operators over time. By March 2002 the availability of rice polish became an important constraint noted during the monitoring period. This was caused by competition from a large-scale pig farming operation that purchased large quantities of rice polish from the local rice mill. This had been missed during the resource assessment. Small, affordable quantities of rice polish became less available at Sirimapura junction. Under these circumstances alternative ingredients such as household food waste were used.

Stocking

Prior to the cage operator and household monitoring survey being implemented in November 2001, 7 of the 24 participants with fish cages were selected for monitoring. The gender of the operator was considered and a sample was obtained by random selection of 3 female cage operators and 4 male cage operators. By the time that monitoring got underway in November 2001, only 2 households out of the 7 households randomly selected for household monitoring were actually operating cages. The two remaining operators, although both female, had differing household characteristics; MAG was a female head of household and THL, a female cage operator with a fishing husband. The small number of households that actually began operating cages could not have been pre-determined and heterogeneity of the households of the monitoring group meant that statistical analyses were not possible. Despite this analytical constraint, the cage adopter households continued to be monitored and the results are presented comparatively with those of non-adopting households.

Stocking of fish cages took place in October 2001. Stocking was conducted in a single event which differed considerably from the situation at USG where fish were stocked on a continuous basis. MAG and THL stocked 47 and 154 fish respectively using fish that were caught by a relation using a cast net. This strategy adopted indicated that for these operators in RAJ, there was no relationship between the number of fish stocked and the abundance of small fish in the catch at that time, therefore no analysis was conducted to relate these two variables as in USG village.

Harvesting

The cages yielded small harvests. THL harvested her cage in April 2002. Her reason for harvesting was that the demands on her time for feed preparation and feeding were conflicting with other activities in the household. Around this period her husband was suffering from a fever and her daughter had given recently given birth to their first grandchild. This increased the demand on her labour for household duties. The revenue from the cage harvest (Rs. 450) was used to pay for day-to-day expenses such as food and other consumable household goods.

MAG harvested her cage in May 2002. Her rationale for harvesting was due to increasing difficulties obtaining rice polish for feed preparation. She also felt that the fish were not growing as much anymore. Similarly to THL, the revenue from her cage harvest was spent on day-to-day household consumption expenses. The fate of the fish harvested and the revenue gained from cage-based fattening by the two cage operators is outlined in Table 5.8.

Table 5.8 Fate of harvested tilapia – RAJ village.

Operator Name	Total Harvested (kg.)	Total Consumed in Household (kg.)	Sold (kg.)	Price (Rs./kg)	Total Revenue per cycle (Rs.)
MAG	4.5	0.5	4	45	180
THL	16	1	15	30	450

Table 5.9 Return on labour for female cage operators – RAJ village.

Operator	Feed preparation time (mins./day)	Feeding (mins./day)	Total mins spent per day	No. of days	Value of fish at harvest (Rs.)	Return on labour (Rs./hour labour)
MAG	26	40	66	219	180	0.75
THL	22	40	62	203	450	2.15

The revenue earned from cage aquaculture was low and there was a poor return on labour. The women fed their cage twice daily according to the appetite of the fish. The labour required for feed preparation and administration is tabulated in Table 5.9. This reflects inefficiencies caused by a combination of low stocking densities and poor fish growth, resulting in an extended culture period.

The poor return on labour reflects the inefficiencies caused by a combination of low stocking densities and poor fish growth, resulting in an extended culture period.

Farmer feed formulations

Both cage operators identified poor growth as a problem. Cage operators prepared feed and fed their fish twice daily; therefore feeding frequency was not likely to be a factor contributing to poor growth. Feed samples were collected each month to provide some indication of the feed quality prepared by participants. At the outset, the concept of including fish in the feed and its subsequent effect of increasing protein was explained. Food scraps were also identified as a feed resource, but were highlighted as having far less protein content resulting in slower growth. Samples were collected from THL and MAG from within the monitoring group and another operator outwith the monitoring group. All feeds were found to contain low amounts of protein. These are compared against the researcher recommended feed of 50% minor cyprinids (fresh, ground) and 50% rice polish. The results of the proximate composition analysis are presented in Table 5.10.

Table 5.10 Comparative proximate composition analysis between farmer-made and recommended feeds at RAJ

Participant Name		Moisture	Ash	Lipid	Protein	n
Farmer-feed	Mean	63.32	10.08	13.08	15.45	8
	St. Dev	10.96	2.68	3.17	7.29	
Researcher – recommended feed	Mean	27.68	11.87	21.26	23.71	4
	St. Dev	5.51	1.18	2.33	0.75	

The moisture content of participant feed was 63%, compared to the recommended diet which was 27.68%. This difference may imply that water was added to help with grinding, however qualitative information collected during the monitoring period indicated that household food waste such as excess rice, bread and coconut were incorporated with fresh fish and fish visceral waste. This is the most probable reason for the high moisture content. The recommended diet was rarely used due to the lack of a consistent supply of rice polish at Sirimapura junction. There was relatively high availability of household food waste and fish visceral waste which were incorporated into the feed. This modification to the proposed method demonstrated the adaptive capacities of operators in response to changing resource availability. Availability of fresh *A. melettinus* and other minor cyprinids was not a constraint for female cage operators. MAG received small fish as payment in kind for assisting in removing minor cyprinids from other fishermen's nets. Although she obtained fish using the same system prior to cage culture, this activity aided her ability to obtain fish as a feed input. THL retained *Glossogobius spp*. and *Puntius spp*., discarded from her husband's catch and ground them into feed.

Alterative uses of cages and feed ingredients

Household food waste was identified as a key feed resource for rearing animals within the village. This is depicted in Figure 5.12. A brief evaluation of the availability of household food waste was conducted using households stratified from a wealth ranking exercise conducted during the situation appraisal. This was used to determine if discarded household food waste was related to wealth status. This indicated that even the poorest households produced 0.5 kg of food waste per day, which had an inherent value as a feed for either fish or chickens.

The other 12 cages remained unmade and were left in the homesteads. In 5 cases the cage materials which were distributed to the households were made into fish holding bags. Others used the cage frames for drying washing. In this case the metal cage materials provided ample opportunity for use in other capacities rather than cage culture. The alternative uses of cage materials as well as feeds is a key consideration when trying to identify opportunities and constraints to the adoption of cage aquaculture in the light of other alternative uses.

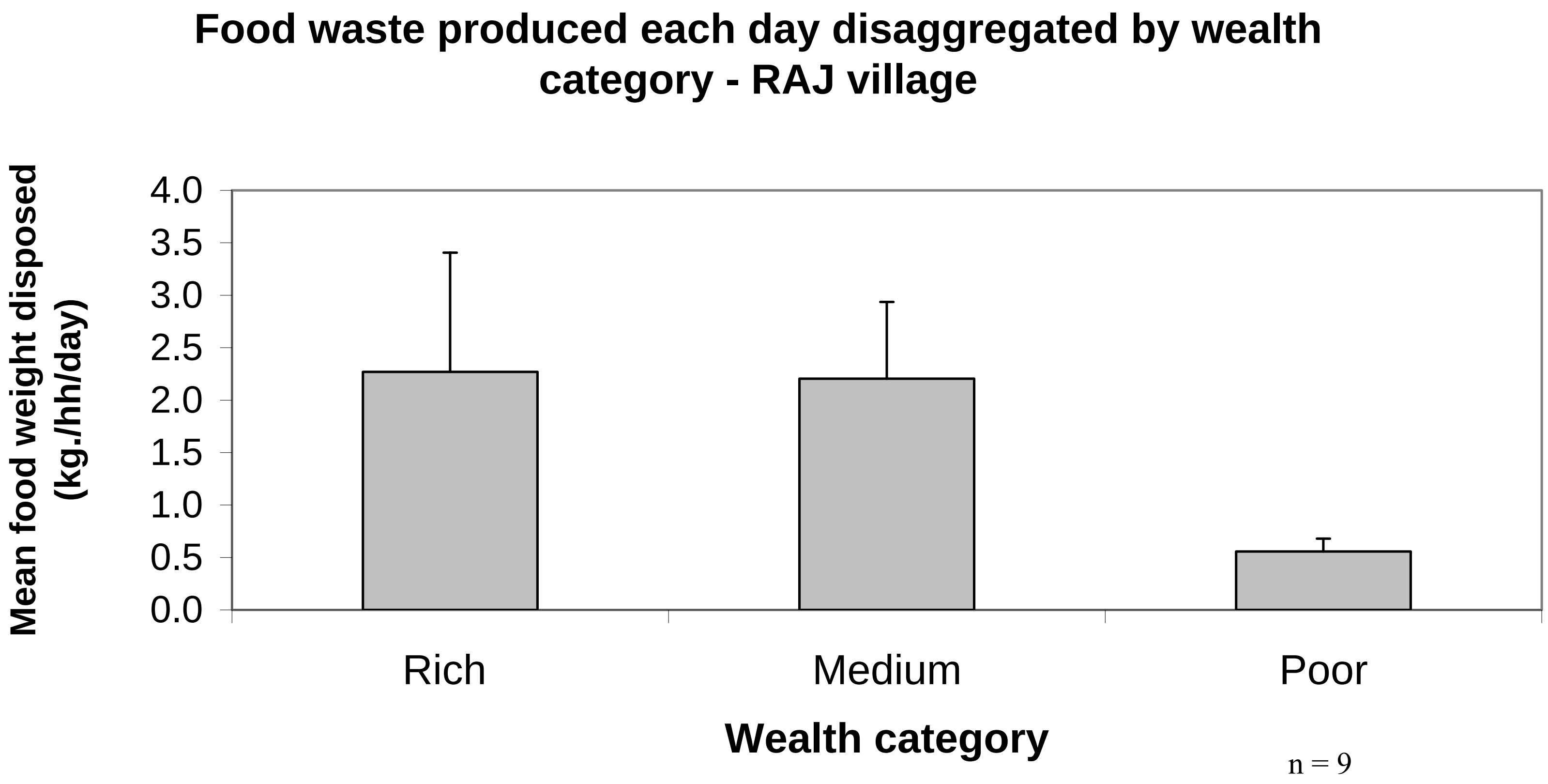

Figure 5.12 Food waste disposed each day in RAJ village

By May 2002 five households in RAJ village had used their cages for stocking chicks. This was investigated and compared to cage-based fattening of tilapia to explore the use of the cage and feed resources to raise animals. Households where cages were being used for chicks were targeted and the householders interviewed.

The main reason cited for their preference for rearing chicken compared to fish was security. Chicken cages could be checked frequently and located in the homestead unlike fish cages which were often located away from the homestead. Fish cages could not be observed as frequently as chicken and were more vulnerable to theft. The cage provided some protection from large predators such as birds and mongoose. One male participant stated that chicken rearing was better than fish culture as there was no requirement to enter the water to feed.

The start up costs of chicken farming were low in comparison to the opportunity costs of stocking tilapia at a high density of 200 fish per cubic metre. Rejected vaccinated chicks were easily available and could be purchased from cycle vendors. Male chicks rejected from layer farms were sold from village to village. Male chicks cost Rs. 10 and female chicks Rs. 12.5 (higher priced due to their productive value for egg laying). After 5-6 months the male village chickens could be sold for Rs. 80 per bird within the village or Rs. 140-150 at market. Once laying, respondents reported that a local female hen could produce approximately one egg per day which could be sold for Rs. 5 each. One respondent mentioned that ten hens would collectively lay 5-6 eggs per day when fed on household waste and free ranged. On this basis egg production could provide an income of Rs. 175 – 210 per week. This was the broadly the equivalent of selling a kilogram of small tilapia each day. Figure 5.13 shows, the wealthier have a greater abundance of household food waste and can support a larger number of poultry than the poor, reinforcing the point that the poor are often condemned to low-level production due to their lack of key resources. Despite the level of household waste available, a particular advantage in this village was the high availability of fish processing waste for free ranging chickens due to fish processing taking place outdoors and the close proximity of households to one another. If the cage and the abundance of household food waste are viewed as production assets, a far better return on investment and labour is achieved by rearing chickens than through cage-based fattening of tilapia when the economic returns of MAG and THL are used as a basis for comparison.

Consumer preference of cage and tank tilapia

Consumer preferences for fish were tested with respondents from four households that were randomly selected within RAJ village. Using the same method as that implemented in USG village participants were asked to score the characteristics of the fish in each group out of a maximum of 5 Slimy skin was generally regarded as an undesirable trait and was scored negatively when participants expressed it as off-putting. The results are presented in Figure 5.13.

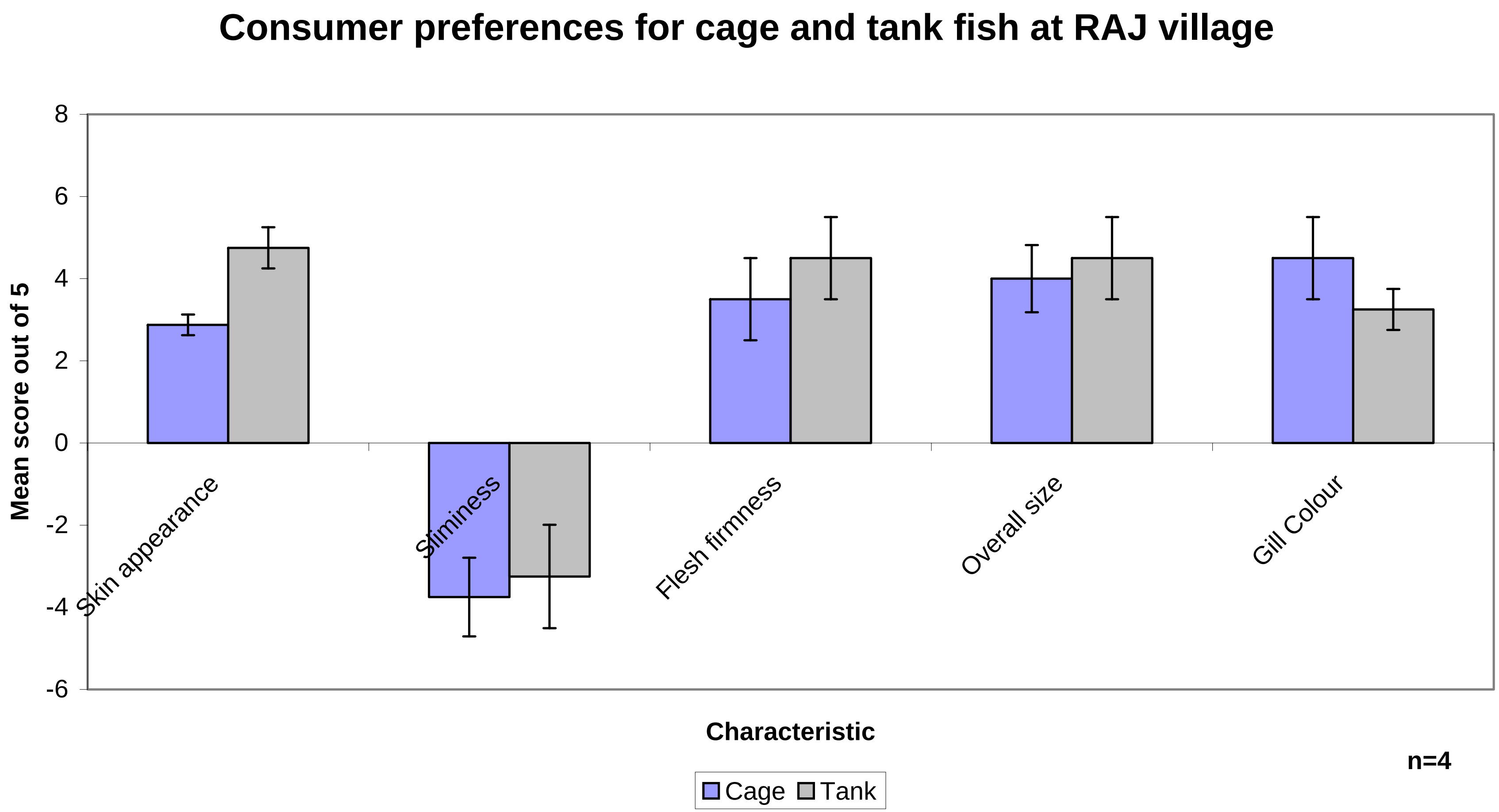

Figure 5.13 Participant scoring of cage and tank fish characteristics

The results indicate that tank fish scored higher than cage fish on all characteristics with the exception of gill colour. As cage fish were harvested and were fresher, the gill colour was brighter. The sliminess of the skin was scored negatively as it was an unattractive characteristic. The fish from the cage were slimier than those from the tank, consequently accumulating greater negative scores than the tank fish. Similar to the cage fish harvested at USG, the RAJ cage fish also turned black when harvested and were scored lower than the tank fish. Participants had an overall preference for fish with paler, whitish skin and scored the tank fish higher on this basis. The darkening of the skin and sliminess present in cage fish post-harvest represents an important marketing constraint when presented alongside fish originating from the tank fishery.

5.3.6 Comparative researcher-managed study

The key results of a researcher managed study are highlighted with full results reported in (Pollock & Little, 2003). Mean food conversion ratio, feed consumption and SGRs are presented below:

- Mean food conversion ratio = 31.78, St. Dev = +/- 7.95
- Mean food consumed by cage (%b.w./day) = 16.43, St. Dev = +/- 4.59
- Mean SGR (♂) = 0.85 , St. Dev = +/- 0.14
- Mean SGR (♀) = 0.48, St. Dev = +/- 0.11

The results indicate a high food conversion ratio which was caused by feeding a large ration to compensate for the impact of invading fish during the trial. The results show that feeding whilst using the metal cage design with 25.4 mm mesh aperture is highly inefficient as invading fish (minor cyprinids) can enter the cage and consume feed intended for tilapia. This constrained an accurate measurement of tilapia feed consumption to be assessed. To investigate the impact of this high food conversion ratio on the economic viability to the system, further sensitivity analyses are presented in Table 5.11 for the metal cage design, assuming a 6-month cage lifespan. The analysis uses the same method outlined in Chapter 3.

The results indicate that cage-based fattening of tilapia is not economically viable under the current system. However, the SGR calculations confirm that fish did grow during the trial period. If feeding could be improved to bring down costs, perhaps the system could be economically viable in the future.

Table 5.11 Economic analysis of cage-based fattening of tilapia using metal cage and recommended diet

Weight at stocking (g)	Cage cost (Rs.)	Assumed cage lifespan (days)	Observed FCR	Duration of culture cycle (days) to 250 g	No. of culture cycles during working life of cage	Cage costs per culture cycle (Rs.)	Feed Cost (/kg)	Assumed stocking density/m3	Opportunity cost of seed (Rs.)	Total costs (Rs.)	Total benefits, 100% survival (Rs./cycle)	Net benefits, 100% survival (Rs./cycle)	Revised benefits, 20% mortality (Rs./cycle)	Revised net benefits, 20% mortality (Rs./cycle)
50	1585.75	183	31.78	313	0.58	2719.67	10277	200	250	13246.67	2000	-11246.67	1600	-11646.67
75	1585.75	183	31.78	234	0.78	2033.24	8932	200	375	11340.24	2000	-9340.24	1600	-9740.24
100	1585.75	183	31.78	178	1.03	1546.65	7647	200	500	9693.65	2000	-7693.65	1600	-8093.65
125	1585.75	183	31.78	136	1.34	1181.71	6394	200	625	8200.71	2000	-6200.71	1600	-6600.71
150	1585.75	183	31.78	100	1.83	868.90	5146	200	750	6764.90	2000	-4764.90	1600	-5164.90
175	1585.75	183	31.78	70	2.61	608.23	3868	200	875	5351.23	2000	-3351.23	1600	-3751.23
200	1585.75	183	31.78	44	4.15	382.32	2590	200	1000	3972.32	2000	-1972.32	1600	-2372.32
225	1585.75	183	31.78	21	8.69	182.47	1308	200	1125	2615.47	2000	-615.47	1600	-1015.47

5.4 Brief conclusions

5.4.4 Critique of the methodology

Stocking and harvesting patterns

The method used could not take into account the daily variability in small tilapia catches as structured monitoring was conducted on a fortnightly basis and catch characteristics from two days were used for the analysis. The analysis would have benefited from fish catch data recorded for each corresponding date of stocking. This was not feasible due to the unpredictability of stocking and shortage of manpower in addition to other monitoring tasks which had to be accomplished for the monitoring group within a designated two - week interval.

The results show low adoption of cage-based fattening within the study period. A large proportion of this is accounted for by technical variables such as cage material performance and low quality of feed which probably affected the growth of fish. The study has identified a number of key constraints to adoption, particularly the low availability of small tilapia in both communities and in particular women's inability to access 'seed' by themselves, without the assistance of a male relative or friend. Feed preparation was initially hindered by the inability to produce fishmeal *in situ*. Furthermore, women in RAJ experienced difficulties in obtaining rice polish when a large-scale pig farm began to compete for the resource. Men in USG also used unsieved rice bran which reduced the quality of the feed constituents.

The results showed that in these circumstances cage-based fattening of tilapia failed to make a significant impact on household income. Despite the low revenue obtained, the most important reason quoted for cage harvests was for meeting either emergency household expenses, such as medication, or to help ease household finances in times of low income. In this way cages could be said to have contributed to reducing household vulnerability, albeit in a small way and not through any significant contribution to income. Cage fish did not contribute to increased household intake of fish as the majority of fish were sold. Stocking small tilapia in cages did not reduce household intake of fish as the numbers stocked were relatively small and fishing continued on a regular basis.

Female cage operators at RAJ had a low return on their labour for the enterprise. However, women were very limited in their opportunities to engage in any other type of wage labour and were more commonly paid in kind for fishing-related work within the community. Therefore, women may have been interested to take up cage culture to seize any opportunity to diversify their income sources and earn cash income.

The results of the researcher-managed feeding trial (Pollock & Little, 2003) highlighted the technical constraints to feeding fish using the metal cage design. This indicated that the system requires further technical development, cage design and feed administration in particular, before the activity can hope to become of economic importance to households. These findings, coupled with the low stocking densities attained by cage operators in both USG and RAJ villages, highlight the current inefficiency of the system and its limited capacity at present to contribute to household income generation.

A major finding was that in either community consumers preferred tank-caught fish to cage- fattened fish. The black colouration and slimy skin observed after cage fish were harvested was a major constraint to their market acceptability, with vendors also reporting that black fish were more difficult to sell. In this case, a key constraint at the marketing end of the chain has been identified and until this is overcome will continue to be a limitation to the adoption of cage-based fattening for producers who intend to sell their fish.

Initial stages in USG revealed that alternative income generating activities were an important factor in the discontinuance of cage culture. In RAJ men either failed to fabricate their cages or failed to stock them. This was influenced by the negative experiences of others who stocked their cages and subsequently experienced stock mortalities. The poor adoption in each community may also be a function of the alternative livelihood activities competing for participants' labour.

Chapter 6 goes on to look in greater detail at the livelihood context in which decisions about whether to adopt cage-based fattening of tilapia are formed. Household livelihood activities and assets are detailed in order to broaden the understanding of context.

Chapter 6 Livelihoods, Vulnerability and Adopter Categorisation in Sri Lankan Villages

The previous chapter indicated the extent to which cage-based fattening of tilapia was adopted and discontinued in the communities of USG and RAJ. The findings indicated several technical and socio-economic constraints to the adoption of cage - based fattening of tilapia. Preference for wild caught tank fish amongst consumers in both communities was also identified as a major limitation to the market acceptance of cage - derived tilapia. Besides these factors discontinuing cage operators in USG indicated their involvement in other income generating activities played a major role in their discontinuance. In RAJ non-adoption or discontinuance amongst men was largely apportioned to the distance of the cage from the household when the tank water spread area was low. Despite increasing tank water spread areas during the *maha* season, many households failed to fabricate and install their cages which indicated that other factors were influential in their non-adoption.

This chapter seeks to use a study of livelihoods assets (human, social, natural, physical and financial capital) as well as a broad overview of the range and value of livelihoods activities to provide further clarity to the socio-economic rationale for adoption or rejection of cage-based fattening of tilapia within the wider context of participants' livelihoods.

Rogers (2003) proposes three governing factors which the adoption or rejection of technology can be attributed to

1. Socio-economic characteristics
2. Communication behaviour
3. Personality variables

Rogers (2003) makes several generalisations in this regard: early adopters are more likely to be wealthier, have a larger unit size (such as land holding which to base operations), are likely to be more cosmopolitan, mobile (socially and geographically) and well educated.

A livelihoods monitoring survey was implemented concurrently with the technical intervention in each community to quantify the socio-economic characteristics of adopters and non-adopters and to indicate if broader livelihood variables could further explain their adoption or rejection of cage-based fattening of tilapia. In addition to complementing the qualitative information gathered on adoption and discontinuance (Chapter 5) this quantitative approach also served as a validation process for the information collected in situation appraisal.

The situation appraisal indicated that fishing was a significant aspect of livelihood activities and in particular the seasonality of fishing contributed to household vulnerability. It was also important to gain a deeper understanding of the fisheries in each tank at the time of intervention as the availability of small tilapia in the catch was a key input for cage-based fattening of tilapia to be a viable livelihood option. Knowledge of fishing and, in particular, income from fishing also complemented the adoption study to understand if there was a real necessity to diversify income sources in the light of seasonal income shortfalls from the fishery.

By following fisheries at different time-scales, variation in fishing tactics and strategies were identified and helped understanding the fishery system in a holistic way (Salas & Gaertner, 2004). The fisheries work in this chapter seeks to unpack the fishing systems employed in both communities and the strategies they adopt to exploit the tank resource in changing seasonal conditions.

Reasons for some participants' adoption or non-adoption of cage based fattening of tilapia are proposed within their overall livelihoods context.

6.1 Methodology

The methods used for the following section were based on questionnaire data collection. The process of developing, testing and implementing a fisheries and livelihoods questionnaire is outlined below.

6.2 Questionnaire Design and Implementation

The structured questionnaire approach to data collection was favoured for its use in making comparisons on several livelihoods components and a structured and coherent form of data collection was required in order for comparisons between households and villages to be made on multiple variables.

Seasonality of income was indicated as a major feature of household vulnerability during the situation appraisal, therefore monitoring focused on the seasonal changes in income from various livelihood activities. Data were then aggregated to provide an overall account of total annual household income.

There was reportedly a marked seasonality in fish catch during the situation appraisal and this was necessary to quantify. In this instance is was necessary to collect detailed quantitative information on catch volumes, composition, gears used and fishing behaviour at a household level, in a consistent manner to allow fishers in both communities to be equally compared. Precise information on catch volume and value was necessary to determine the economics of fishing to be used in further analyses of opportunity costs of labour activities in the communities studied. This is addressed in chapter 5. The longitudinal monitoring questionnaire is described below and its final draft is presented in Appendix 8.

The manifestation of seasonality relates to the pattern of monsoon rainfall. This dictates water availability of crop irrigation patterns and consequently affects cultivation cycles.

The absence of large negative natural or economic shocks to fishers and farmers in the area, and relatively good access to goods and services and provision of basic assets, means that vulnerability of householders livelihoods was mainly seasonally mediated. Livelihoods within the farming and fishing communities are completely dependent on the predictability of water supply for the sustainability of their livelihood. This situation is described as having a high covariate risk (Ellis, 2000).

However, agriculture has become a subsistence activity for many households, with substantial proportions of the harvest retained for household consumption and some paddy sold to repay cultivation loans or release pawned goods. Incomes from Middle East remittances were sporadic in nature and often designated for a purpose such as house construction or saving rather than for immediate spend and are a long-term strategy. The impact of seasonality on livelihoods will focus on these two principal income sources of fishing and agriculture, which are the main causes of livelihood vulnerability. Key features of these livelihoods will be presented and discussed.

To develop an appropriate questionnaire, sensitive to the prevailing situation in USG and RAJ villages, several drafts had to be made and tested in the field. To enable a broader livelihoods analysis to be conducted three types of questionnaire survey were carried out:

- An initial baseline questionnaire was designed to investigate assets, access and activities of households engaged in fishing.
- A longitudinal monitoring questionnaire to collect structured data on key characteristics of fishing such as catch volume, composition, net mesh size and number, time spent fishing and active fishing behaviour over a longer period at frequent intervals.
- A household level livelihoods questionnaire conducted over the same longitudinal monitoring period.

The fisheries questionnaire was implemented at the same time as the household livelihoods questionnaire with similar structures and questions used for each community. The questionnaire was revised four times after testing and discussion with local field staff before a final draft was agreed. The complexity of the fishing gears used necessitated repeat visits to fish landing sites to discuss and view gear types and uses during the situation appraisal and questionnaire field-testing stages.

The questionnaire was written in English and questioning was undertaken in Sinhala by the enumerator. The questionnaires were designed to enable easy and speedy enumeration without any compromise in accuracy and to avoid participant fatigue. Interviews averaged around one hour per household for both the household livelihood and fishing questionnaires to be completed simultaneously.

Answering questions relied on participant recall. The events of the last 2 fishing 'sessions' were easily recalled by fishers and enumerated by the interviewer. Calculation of data values over two fishing sessions per monitoring period enabled greater resolution than using recalled data from a single fishing session.

6.2.1 Stratification of monitoring groups.

Monitoring groups were allocated to represent a sample of cage operators and non-cage operating groups in both communities. In USG this was conducted with 4 operators who continued cage culture during the monitoring period and with 5 non-operators who were randomly selected from a list of households engaged in fishing.

The situation in RAJ village differed from that of USG. Originally materials for fabrication of 24 cages were distributed to the participants in September 2001. Of the group who received cage materials 7 households were randomly selected based on an assumption that they would operate cages.

Within the cage operator household group, however, cages were not fabricated and only two households adopted i.e. the fabricated their cages and operated them. A further 3 cage operators discontinued cage culture shortly after the intervention monitoring began and 3 people with cage materials allocated did not fabricate and operate their cages within the monitoring period. This meant that monitoring cage operator behaviour was restricted to the activities of 2 remaining adopters. Their case studies are reported, however, no generalisations should be drawn from such a small study size.

A group of 7 households without a fish cage were selected for comparison.

For this reason, comparative analysis of cage operator group characteristics and those of non- cage operating groups were abandoned as low adoption levels of the technology rendered this analysis non-viable.

Due to the low adoption levels witnessed, a comparative statistical analysis was not possible in either community. Therefore, results are presented on an individual basis where some key characteristics of adopters and non-adopters are discussed.

6.2.2 Household selection

For ease of interview, and to make the association between fishing and household livelihood and incomes, the same householders were interviewed for the livelihoods and fisheries questionnaire surveys. The criteria for selection were different in each village.

USG

The main constraint dictating sample size was logistics. Villagers were often busy in the home or were away from the home for agricultural labour or other personal affairs. Consideration had to be given to the feasibility of the sample size given that one interviewer would be responsible for the enumeration of the entire sample during the specified monitoring period. Therefore 10 households were selected for longitudinal monitoring based on the capacity of one researcher to interview these fishing households consistently. The monitoring took place over a one-year period from July 2001 to June 2002.

It was hypothesised that fishing practice and cage operation strategy were related. To permit investigation of that hypothesis the selection of participants was narrowed to 2 groups cage operators and those without cages as a "control group". Many cage operators started and subsequently dropped out of cage culture within the first few months of the project, the remaining number of cage operators at the point when monitoring commenced was five. Since all members of the cage operator group were fisher-farmers apart from one, whose livelihood comprised of both fishing and vending, all cage operators were selected for monitoring and a control group was randomly selected from fisher-farmer households in the village.

The sample of fisher-farmer households was selected from a list of people registered with the fisherman's co-operative society. Triangulated key informant interviews with several fishermen, established a pre-selected list of fisher-farmer households where fishing was a regular part of the livelihood. Furthermore, respondents were asked to indicate if the members had independent households i.e. the members were not from the same household unit. This was important to establish as some young fishermen listed as members' lived in the parental home and could not be classified as independent householders. It was found prior to the implementation of the household monitoring survey that many of these younger fishermen were involved in other income generating activities and were difficult to meet for interview. At the time of the sample selection many of the younger fishermen, typically in their late teens to mid twenties, were involved in the construction of a new fishing village and were often out of the household. Therefore, independent fishing-farming households, excluding young fishing households, were randomly selected from this list so that there was an improved likelihood of meeting the selected householders on a regular basis.

10 households, 5 with a cage and 5 without a cage, were selected for the monitoring group. Within a short period of time the number of cage operators was reduced to 4 so the groups consequently became 4 cage – operating households and 5 fisher-farmer households without a fish cage.

RAJ

RAJ village, located on Rajangana tank, was selected to provide an alternative village in which the feasibility of cage-based fattening of tilapia was tested. Since the preconditions for cage operation were access to the tank, access to live fish for stocking, access to feed ingredients and time, many of the householders in the village expressed an interest in participating in the research and cages were distributed to 24 households.

Similarly to the questionnaire used for data collection in USG, the RAJ questionnaire was field tested and redrafted several times.

Since the cages had been designed and tested in USG, and this was not necessary to repeat in RAJ, the household-level monitoring was began immediately after the project intervened.

Following the same rationale that cage operation and fishing behaviour may be linked, a group of cage operators and control group of non- cage operating fishing households were selected for the study. This comprised 7 fishing only households and 7 households with a fish cage. The criteria for selection were stratified into the groups noted in Table 6.1. Given that the number of households with fish cages was greater in this village the selection of participant in the cage-operator group could be randomised. The cage operator group was stratified by gender to allow differences in household head gender and livelihood activities, income levels and cage operation strategies to be examined.

Key informant interviews with fishermen indicated that the number of years of fishing experience was an important key factor to them that could account for differences in success of fishers. A list of fishing households was collected from the president of the fishing co-operative society and the number of years fishing experience for each member was established through interviews with key informants. By establishing the distribution of the number of years fishing experience, the group was subsequently stratified into a group of fishers with under 15 years fishing experience and a group with more than 15 years fishing experience.

Differences between these groups will be examined during the analysis of factors affecting fishing success.

Table 6.1 Sample stratification in RAJ village

Group	Characteristic	Number of respondents
Cage Operator	Female headed household	3
	Male headed household	4
Fishing only “control”	Male headed household <15 years fishing experience	3
Fishing only “control”	Male headed household >15 years fishing experience	4
Total number of respondents		14

6.2.3 Data Collection and Analysis.

The aim of this part of the research was to define factors affecting fishing success and the overall vulnerability of fishing households in both of the villages studied. Data collection also sought to identify key differences in fishing strategies between cage-operators and non-cage operating fishing households. Data was collected over a twelve-month and eight month monitoring period in USG and RAJ respectively.

6.2.4 Baseline household questionnaire

In order to establish their assets, access and activities, a baseline questionnaire was developed, tested and implemented with all of the households in the monitoring group. Values computed were used in the analysis of variance to identify key differences in asset distribution, and essentially wealth, between household types (namely male and female-headed households) in RAJ village and between cage operators and the non-cage operating control group in both villages. Variables used to ascertain the assets of each household are outlined in section 6.2.5. Debt is investigated in this analysis since the situation appraisal indicated that indebtedness and pawning household assets was commonplace in both villages.

6.2.5 Assets

The five capitals outlines in the DFID Sustainable Rural Livelihoods framework were examined. The exact variables forming these capitals are outlined below:

Human Capital.

The total household capacity to earn based on human labour was measured using the number of household members in adult equivalent units (AEU). AEU accounts for the variability in household human capital caused by gender and age differences. The number of earners per household was also noted to complement this data. The education level reached for each member of the household was recorded, in particular those who were educated beyond 15 years, gaining basic high school qualifications. Health status of particular individuals was not recorded officially within the questionnaire, although this information was recorded during longitudinal monitoring.

Social capital

In this analysis the number of societies and institutions which households were involved in was recorded. Those holding office bearing positions such as President or Treasurer within the organisations were given a higher score i.e. 1= member, 2= office bearer. This measurement is presented for different adopter categories.

Natural Capital

Land, water and forested areas are discussed within the wider village context. The results indicated the extent to which participants could benefit from open access resources.

Physical Capital

Although land quantity has no direct bearing on the ability to adopt a water-based aquaculture system, such as cage-based fattening of tilapia, the quantity of land owned by a household is inextricably linked with some degree of wealth (through lack of fragmentation or non-rental status).

Fishing and agricultural asset values were noted to indicate the extent to which these assets were accumulated in respect of the relative contribution of these activities to the total households income. Variability in these assets is also shown between households

Financial Capital

Assets that could be liquidated in times of crisis were recorded. These included jewellery, livestock and savings. The total amount borrowed per year was also noted which indicates the household's access to credit. This included borrowing from local banks as well as informal money lenders and local shops.

6.2.6 Longitudinal monitoring questionnaire.

A longitudinal livelihood questionnaire was introduced to complement the asset and access-based information collected in the baseline questionnaire and to enhance understanding of the impact of seasonal change on household vulnerability. Seasonality was identified as one of the key factors that influenced household vulnerability during the situation appraisal. The manifestations of this in the households surveyed were the seasonal changes in fish catch per unit effort described in Chapter 4 and the seasonal changes in the income from farming and demand for and availability of labour opportunities.

Seasonal livelihoods monitoring was focused on collecting data from the following areas**:**

- Income from agriculture (paddy and dry crops)
- Income from fishing
- Income from off-farm wage labour
- Income from remittances and benefits
- Expenditure and prices of food items
- Expenditure on consumer items including medicines
- Expenditure on large consumer items
- Repayments of existing household debts
- New credit agreements undertaken

Prevalence and attendance at social events such as meetings for the fishing or farming societies were also monitored and any conflicts at these events recorded.

Initially, data was collected with cage operators and a control group of non-cage operators, with the intention that the groups could be compared to demonstrate any economic impact of cage culture on livelihoods. After several months of monitoring, cage culture was deemed infeasible as cages were either poached, or yielded so few fish that their economic contribution to the household was negligible. Another constraint was the heterogeneity within groups of cage-operators and non-cage operating groups. This variability meant that the effects of cage operation could not be detected statistically against such “noise” in the data set. This finding meant that between groups comparisons were not conducted as they added little to our understanding of the key factors governing adoption of cage-based fattening of tilapia or the social or economic impact that it had on the cage operator households compared with non-operating households.

The factor with the greatest impact on household vulnerability is seasonality. Given that fishing accounts for a considerable portion of household income, the characteristics of fishing seasonality were examined to investigate to what extent fishing seasonality contributed to household vulnerability. Key features of the fishery such as the relationship between water spread area, CPUE, catch composition and gear types were studied. This examined the impact of seasonal changes tank capacity measured as the water spread area (in cubic kilometres) affected CPUE and also the extent to which fishers’ responded to seasonality. CPUE in the gill net fishery was measured as the catch (kg) per gill net/ hour/ day. This accounted for any variation in fishing time or numbers of gears used. For the trammel net fishers CPUE was measured as the catch (kg) / hour of active fishing.

6.3 Results

6.3.1 USG Case Study

Investigation of assets is followed by a more detailed examination of fishing assets and activities which also highlights seasonal variation over the monitoring period.

Assets

Rogers (2003) states that innovators and early adopters are better educated than other groups. Despite the small number of cases studied, however, this does not appear to be supported in this analysis.

Human Capital

Human capital characteristics of adopter, non -adopter and discontinuer households such as education level reached, are outlined in Table 6.2.

The results show that there are more females than males educated beyond 15 years of age in each household irrespective of adopter category. In some households, in particular younger couples, women have gained higher educational attainment than men. This was observed in MBA, NAN and AJN's households. This may be due to a tendency for young men to leave school in order to undertake fishing to start earning, whereas girls continue at school as the households are less dependent on them for income generation. In other households, with the exception of WML, it is the children in the household which account for higher numbers of female members educated beyond 15 years of ages. Hence, Roger's assertion that adopters are highly educated does not resonate in this dataset as some adopters were found to have no formal education beyond 15 years of age, and one adopter was illiterate. Similarly the discontinuer and non-adopters categories are not disadvantaged in this respect and exhibit similar characteristics.

Household size (AEU) is similar between adopter categories. There are more earners per household in the 'adopter' households of WAN and GNE where remittance income is received from sons who were fishing and contributed part of their earnings to the household. The number of household earners does present a constraint to the household earning capacity as a unit, however the types and productivity of the income generating activities in which they engage is also important and more likely to be a key factor in overall income generation.

Table 6.2 Adopter status, human, social and natural capital in USG village

		Human Capital					Social Capital		Natural Capital	
Respondent Name	Adopter status	Household size (AEU)	Number of earners in household	No. of household members with education beyond age 15	Male Educated > age 15	Female Educated > age 15	No. of Society Memberships Held	Office Bearer Score	Paddy land value (Rs.)	Highland Land Value (Rs.)
GNE	Adopter	3.66	4	0	0	0	5	2	250 000	80 000
WAN	Adopter	5.49	4	2	1	1	2	2	0	0
MBA	Adopter	3.89	1	1	0	1	3	1	0	0
NAN	Adopter	2.33	2	1	0	1	3	1	40 000	0
WIJ	Discontinuer	2.66	1	1	0	1	2	1	15 000	0
WML	Non-Adopter	3.39	1	2	1	1	3	1	50 000	25 000
SIM	Non-Adopter	5.49	3	4	2	2	2	1	80 000	0
SUR	Non-Adopter	3.29	1	0	0	0	3	1	80 000	30 000
AJN	Non-Adopter	2.33	2	1	0	1	1	1	0	0

Social Capital

The results presented in Table 6.2 indicate that adopters were members of more societies than non-adopters and have greater power within community organisations as office bearers. As the selection process for organisation office bearers was democratic this indicates that these individuals are well respected consequently having greater social capital than others within the community. These results confirm despite the small size of group surveyed, that those adopting cage-based fattening of tilapia seem to have higher social status than those who are non-adopters or discontinuers.

Natural Capital

Land

The value of household land assets is presented in Table 6.2. The data shows that land holdings are highly variable between households. On this criterion, and given the small number of households surveyed, there appears to be no relationship visible between adopters or non-adopters. In USG land originally allocated under the Mahaweli Development Programme in the 1950's has become fragmented over subsequent second and third generations. Land retained within the family unit and not rented out to tenant farmers is normally cultivated at the same time and the harvest (minus inputs) is divided proportionally amongst the separate households within the family. Land is still ranked as one of the most common indicators of wealth and therefore was included as an indicator in this assessment. The wealthiest people are commonly cited as those retaining ownership of their original 0.4 hectares of paddy land where others have had to fragment their land between other generations or rent land. Culturally and socially the ability to own or rent land is very important to secure paddy for subsistence. After harvest, bushels[1] of paddy are used to settle loans or reclaim pawned items which have been used to access credit for agricultural inputs. Thereafter, paddy is retained in the household for consumption and only sold in an emergency when cash is needed.

Water

Each household had access to the tank. Bathing, washing clothes and livestock watering was normally conducted at the tank where no access restrictions were placed on individual use. Although access to fishing was meant to be controlled the tank was in reality an open access resource as regulation of access was never implemented and entrants to fishing were tolerated by most.

Access to wells was important within the village. Every household within USG had access to drinking water, the wealthier people had their own well. Households that did not own a well were often permitted to use neighbours wells, which highlights that access to resources such as water is more important than ownership for some people. A communal well within the village was maintained through an organised community work group run by the Samurdhi Society for villagers who did not have access to private well. At least one member in each household receiving Samurdhi benefits was duty bound to participate in 'Shramadana[2]' when required or risk losing their entitlement to benefits.

[1] Unit of weight measurement 1 bushel = 22 kg.
[2] Shramadana is the name of the work event organised by the Samurdhi Society.

Forests

There were no access restrictions on the local jungle areas. Slash and burn agriculture (*chena* cultivation) was banned by the government and timber abstraction was regulated. Despite this legislative ban on forest encroachment and abstractions, numerous contraventions of legislation were observed during the monitoring period. Timber abstraction within the jungle area was commonly practiced by younger men within the village and could be lucrative depending on the types of timber felled. Village expansion into jungle areas was partially to blame with more homesteads being constructed leading to deforestation of jungle areas. This encroachment into previously forested areas had reportedly led to an increase in elephant damage to homesteads, home gardens and agricultural land. Access to forested areas provided employment opportunities, particularly for young men, but also was a potential supply of wood for cage materials, necessary if any further participants wish to construct cages from *ipil ipil* (*Leucaena leucocephala*) bamboo or other local wood varieties.

Physical Capital

Land Value and Ownership

The land holding by participants in varying adopter categories is presented in Table 6.3. Land valuations were based on participants' estimations of value at the time of the survey. Land is rarely sold in USG village and is principally used for the cultivation of paddy for household consumption. Two types of land are categorised as paddy, irrigated and used principally for rice cultivation and highland, which is used for the cultivation of dry crops such as chilli and onions in the *yala* season. Most households in USG own land allocated to their family during settlement. This land is either rented out or cultivated by the family themselves. The land may be fragmented between the younger and older generations of the family and in many cases the original two acres of paddy land allocated at settlement has now been sub-divided between children of the second generation. The importance of land holding size to wealth status was identified during the wealth ranking exercise. Despite cultivation being viewed by many farmers as a subsistence rather than profit making practice, land holding's relationship to perceptions of household wealth underscores its social importance in USG's community. The large variability in landholdings in the USG data reflect the degree to which land holding is retained within the households. Large standard deviations for the mean value of household landholding are influenced by variability between farmers. Two farmers in USG managed to retain their original 0.4 hectares of paddy land without fragmentation, whereas three other participants were landless, one renting land on which he cultivated paddy. With the exception of these cases, all other farmers had their original paddy land fragmented.

A far greater investment was made in fishing assets when compared to agricultural assets. This is linked to the relative value and contribution of the activity to overall household income, examined in Table 6.6. From the data presented in Table 6.3 adopters appeared to invest greater amounts in fishing assets. This is largely explained by their investments in fibreglass boats and ownership of their own craft. Table 6.7 detailing fishing assets indicates that wooden craft are more common amongst non-adopters and two members of this category borrow boats from their fishing partner. The value of landholding is variable in both groups. Large unit size such as large farm size have been associated with innovators and early adopters, however, this is largely irrelevant in this context as the trial in question did not involve land or crops and with the exception of GNE the other three adopters ranged from landless (MBE) to small land owners (NAN) and land renters (WAN). The value of land quoted by GNE refers to his original 0.4 hectares of allocated paddy, however, in practice, when his land is cultivated, 50% of the paddy harvested is given to his son in a neighbouring household. This indicates that his land is fragmented in practice although official ownership of 50% of the land had not been conferred upon his son. Ownership of highland land is also highly variable between groups. GNE used his to cultivate crops such as large onions, chick peas and bringal. WML was found to have consistent income from crops such as coconut and tamarind cultivated both in his home garden and highland land. SUR did not cultivate his highland land in the year of the survey. The value of agricultural assets was also found to be highly variable in both adopter, discontinuer and non-adopter groups. This variability was also not apparently related to agricultural land value, as participants such as WAN (a land renter), MBA (landless) and AJN (renting land) all had invested in some agricultural assets such as a mamotes[1] and large knives. Chicken cages were also integrated into this calculation.

[1] Agricultural tool similar to a hoe

Table 6.3 Physical capital and adopter status

		Physical Capital				
Respondent Name	Adopter status	Value of Fishing Assets (Rs.)	Paddy land value (Rs.)	Highland Land Value (Rs.)	Value of Agricultural Assets (Rs. Excluding land)	Transport assets (Rs.)
GNE	Adopter	28 750	250 000	80 000	6200	2500
WAN	Adopter	6 600	0	0	7600	83 000
MBA	Adopter	10 000	0	0	1800	72 000
NAN	Adopter	18 860	40 000	0	4400	6000
WIJ	Discontinuer	5 500	15 000	0	500	1500
WML	Non-Adopter	13 000	50 000	25 000	0	66 000
SIM	Non-Adopter	8 000	80 000	0	5300	3000
SUR	Non-Adopter	8 300	80 000	30 000	1070	2500
AJN	Non-Adopter	5 250	0	0	800	2000

The value of transport assets was taken as indicative of the participant's ability to travel. All households, irrespective of category, had a bicycle that was used for local travel. Two households in the adopter category had greater transport assets. Both MBA and WAN owned motorbikes that facilitated their travel outside of the village to visit marketplaces such as Galgamuwa and Meegalewa. MBA's house was located on the main road between USG and Meegalewa and could access that market within 30 minutes by motorbike. He used his motorbike to undertake fish vending on a seasonal basis when catches were high. In some cases vegetables were purchased in Meegalewa and sold for profit in the village. This exploitation of marketing opportunities demonstrated his extensive mobility and awareness of market prices and demand in villages outside the area. Although this behaviour is likely to have been facilitated by his use of motorbike, the fact that other motorbike owners have not undertaken this type of activity suggests that MBA has an entrepreneurial personality trait. His fish vending enterprise is also highly compatible with cage-based fattening and may explain his adoption decision.

WAN used his motorbike to visit the *pola* in Galgamuwa and also to bring his children to and from the town for doctor's appointments and purchases of school consumables. This contact with people outside of the village may have developed a range of cosmopolitan traits including discussions with other traders, good understanding of marketplaces and prices.

Despite these two examples motorbike ownership does not imply that adoption of cage-based fattening of tilapia will follow. WML, a non-adopter, also owned a motorbike which was used for local travel to Meegalewa and Galgamuwa to sell crops from his home garden on a regular basis. This facilitated his contact with traders and potentially contributed to his ability to develop external awareness and cosmopolitan attitudes, a trait often associated with adopters. His entrepreneurship led him to develop links with traders to sell his home garden produce such as coconuts and tamarind, rather than develop interest in adopting cage culture.

Financial Capital

Access to financial capital was explored by evaluating the assets which households owned and which could be sold or drawn upon in times of hardship. Early adoption of technology is often synonymous with wealth i.e. access to financial capital, which is sometimes associated with a household's ability to absorb shocks and negative trends or seasonal effects. Table 6.4 indicates that households build up different forms of financial capital.

Jewellery is regarded as a source of financial security in USG. This is commonly received as a wedding gift. Typically jewellery is valued as a means of saving when households mistrust local financial institutions or when there is a lack of their provision. It is also readily pawned for cash. Variable values of jewellery are found in both adopter and non-adopter households. WIJ, the discontinuer, held no savings in jewellery.

Table 6.4 Financial Capital and Adopter Status, USG village

		Financial Capital				
Respondent Name	**Adopter status**	**Value of Jewellery (Rs.)**	**Total Livestock Value (Rs.)**	**Savings deposited in past year (Rs.)**	**Total cash borrowed in past year (Rs.)**	**Total Annual Income (Rs.)**
GNE	Adopter	25000	2120	2300	4000	121381
WAN	Adopter	5000	13500	10000	0	128390
MBA	Adopter	12000	900	1500	5000	59664
NAN	Adopter	18000	37750	6700	1000	175722
WIJ	Discontinuer	0	0	1250	5000	95543
WML	Non-Adopter	1000	250	3895	0	134121
SIM	Non-Adopter	21000	9500	1500	0	102993
SUR	Non-Adopter	10000	1320	600	3800	99302
AJN	Non-Adopter	6000	0	29000	0	206808

Livestock was also cited as an important source of productive financial capital. The most commonly held form of livestock was poultry. Poultry were favoured owing to their ease of feeding, security within the homestead area and easy access to chicks (low start up costs). In Table 6.4 a greater emphasis on livestock holdings is exhibited in the adopter category. This perhaps indicates their willingness to diversify into other income generating activities as a means of coping with risk. AJN's (non-adopter) father has 20 milk-producing buffaloes and although he is not the owner of the buffaloes, he receives the income from their milk. This is not highlighted in Table 6.4 where only the cash value of livestock is presented.

The ability to accept and cope with risk is a characteristic of innovators/ early adopters. Their familiarity with livestock rearing may have made the concept of cage-based fattening of tilapia a less abstract concept to deal with and influenced their decision to adopt. Not only is greater value placed on livestock holding by the adopter group, but also the range of animals kept is more diverse. This strategy may have been adopted to mitigate the impact of disease on one particular animal type; however, this was not qualified with participants during the study.

The ability to save, i.e. build financial capital, is important to establish to what extent a household is impoverished. The amount of savings deposited can be influenced by other features of livelihoods irrespective of agricultural or fishery related incomes. An example of this is the impact of Middle East remittances. This is observed in AJN's household income data where large sums were sent from the Middle East during the monitoring period and were subsequently deposited in the bank. This was also the case for NAN, although rather than deposit the money in a bank, he used it to purchase materials to construct a larger home. Savings are highly variable in all groups and skewed by the impact of remittances on ‘normal’ household saving behaviour. Borrowings and savings do not appear to be interconnected as household circumstances and attitudes towards borrowing may influence this decision. AJN, having made greater deposits in the banks and with the highest annual income of the monitoring group, borrowed less money throughout the year than those with fewer savings. Another form of financial management also exists where smaller deposits are made but borrowing is also minimised. WAN from the adopter category and WML and SIM from the non-adopter category exhibit this strategy. This may be indicative of their financial security and good management of finances as households can manage without the requirement of external support or intervention. This may also be possible as they have sufficient income flow from a variety of sources to enable immediate payments on goods that other have to borrow money to attain.

Households with the lowest incomes, below Rs. 100 000 per annum, save the least and borrow the most cash in total. This is indicative of their inability to save money to invest and to have to borrow money to cope with unexpected expenses or for investment in income generating assets such as fishing nets or agricultural inputs.

6.3.2 Household Income and Adopter Category

Table 6.5 indicates households ranked in order of their mean annual income and adopter status. This table shows that there is no clear pattern to suggest that adopters are consistently wealthier in cash income terms than non-adopters. However, when those households with annual incomes of less than Rs. 100 000 per annum are considered (from rank 6 to 9), 3 out of 4 household of those households have not attempted cage culture, which may suggest that there is some effect when household income falls below this threshold.

Table 6.5 Adopter status and income ranking

Name	Adopter Status	Income Ranking
AJN	Non-adopter	1
NAN	Adopter	2
WML	Non-adopter	3
WAN	Adopter	4
GNE	Adopter	5
SIM	Non-adopter	6
SUR	Non-adopter	7
WIJ	Discontinuer	8
MBA	Adopter	9

The findings suggest that neither income, nor income sources, affect adoption. This is further is confirmed when the total household income (Rs. /annum) and their percentage contribution to annual household income are examined in Table 6.6. This table shows that although income levels are variable in each group, there are no apparent patterns of income or sources of income to suggest that all adopters exhibit different behaviour from discontinuers or non-adopters. Therefore, relating total household income to a household's likelihood of adopting the technology in USG, is inconclusive, and likely due to the small dataset from which this analysis was drawn.

Table 6.6 Total annual household income and proportion of annual income derived from differing income generating activities, USG village

Household Name	Adopter Status	Paddy Farming (%)	Fishing (%)	Middle East Remittances (%)	Other Remittances (%)	State Benefits (%)	Fish Cage (%)	Wage Labour (%)	Other Income (%)	Total Income (Rs. / annum)
GNE	Adopter	21	48	10	0.05	4	1.50	10	1	121381
WAN	Adopter	32	41	0	0.07	4	0.47	16	1	128390
MBA	Adopter	0	81	0	0	8	1.04	9	0	59664
NAN	Adopter	11	49	30	0	0	0.51	0	9	175722
WIJ	Discontinuer	23	48	0	0	5	0	0	25	95543
WML	Non-adopter	28	59	0	0	3	0	0	10	134121
SIM	Non-adopter	54	36	0	0.08	1	0	0	0	102993
SUR	Non-adopter	30	43	0	0	5	0	22	0	99302
AJN	Non-adopter	0	31	28	0	0	0	13	28	206808

Fishing assets

Fishing is a key source of income for households in USG village. The value of household assets apportioned to this is indicative of the importance placed on it as an income generating activity. Critically important is the ownership of a sufficient number of fishing nets and a boat. Fibreglass boats, initially introduced to the village through a government subsidy scheme are one key asset that has been adopted in favour of the traditional wooden dug-out canoe. These fibreglass boats were adopted due to the availability of subsidises in the early 1980's but are more generally recognised as having increased stability, making fishing in poor weather conditions more feasible, and increased durability. Credit could also be raised to purchase a fibreglass fishing boat. The same is true of fishing nets, with vendors often subsidising or lending money for net purchases. This is indicative of the importance and financial benefits which fishing is regarded to have within the community. The importance of fishing in livelihoods is highlighted by both these tables and merits individual consideration. Findings are not conclusive to suggest that the income from either fishing or ownership of fishing assets are related to any particular adopter category. This table does, however, demonstrate that income from fishing forms the major source of income for all households and that the investment in fishing assets is greater than those invested in agriculture.

The tables served to highlight a key point – fishing assets and activities are highly variable between individuals. This is emphasised further in the forthcoming analyses.

Table 6.7 Fishing assets and income from fishing in relation to assets and adopter status

	Adopter status	Income from Fishing (Rs./annum)	% Income from Fishing	Value of Fishing Assets (Rs.)	Number of Nets Owned	Type of Boat Owned
GNE	Adopter	58534	48	28 750	9	Fibreglass
WAN	Adopter	52340	41	6600	9	Wooden
MBA	Adopter	48599	81	10 000	10	Fibreglass
NAN	Adopter	85747	49	18 860	7	Fibreglass
WIJ	Discontinuer	45862	48	5500	5	Wooden
WML	Non-Adopter	79050	59	13 000	22	Wooden
SIM	Non-Adopter	37303	36	8000	8	Wooden
SUR	Non-Adopter	42213	43	8300	6	Fibreglass (shared)
AJN	Non-Adopter	64440	31	5250	7	Wooden (shared)

6.3.3 Seasonality of fishing USG

Seasonality of fishing was identified as a key area of livelihood vulnerability during the situation appraisal. Any fluctuation in the fishery and of its ability to support household income will contribute significantly to livelihood security. The results in Table 6.7 identify that household level investment in fishing assets is considerable, conveying the importance of fishing within the households studied. This section examines to what extent incomes from fishing are seasonal to support or refute participant assertions regarding seasonality made at the situation appraisal. The impact of water spread area (linked to monsoon rainfall and irrigation uses) is examined in relation to total CPUE, to verify if this had an impact on catch. Changes in catch composition and responsive fishing behaviour are also included in this analysis.

Table 6.8 depicts household income from fishing over the 12 - month monitoring period. The mean values per month seem to indicate that with the exception of December 2001 there was little seasonal fluctuation in the catch. However, large standard deviations suggest that there is great variability between individuals, which is a reflection of variations in fishing effort and gear types used. This confirms that fishing is sensitive to seasonal variation and increases livelihood vulnerability. Disaggregating the data also highlights that the each household's characteristic fishing practices vary substantially.

Table 6.8 Income from fishing (Rs./month) of participants in USG village

Month	GNE	WAN	NAN	MBA	WIJ	WML	SIM	SUR	AJN	Mean Income Per Month (Rs.)	St. Dev
	Adopters				Discontinuer		Non-Adopters				
July-01	4458	8011	2914	10748	-	7454	8152	2773	1881	5799	3214
August-01	3183	4378	4495	6755	3000	6113	5555	3464	1750	4299	1623
September-01	5550	1350	1936	10800	5213	9188	4725	3150	12040	5995	3847
October-01	2868	5583	4654	7903	3516	6951	5116	5134	4620	5149	1558
November-01	6291	6483	6478	7434	5011	4402	5719	4350	3815	5554	1221
December-01	2302	2911	2030	4386	3942	4975	3099	3915	1540	3233	1153
January-02	4205	3563	3459	5100	4247	6694	4238	4247	2153	4212	1234
February-02	3441	3492	4941	7388	5372	6750	5944	3084	700	4568	2091
March-02	6885	4636	3434	5084	4071	4451	4042	3004	1553	4129	1469
April-02	6019	4706	4022	7903	1500	6300	7144	2067	3078	4749	2258
May-02	9171	4948	4649	6715	2003	8292	7558	3030	1969	5371	2708
June-02	4163	2278	5588	5531	4988	7481	3150	3994	2205	4375	1719

Seasonal variation in catch composition is also relevant. Higher value fish such as large tilapia, preferred by vendors, are more apparent in the catch in September, October, March and April. However, this representation is composed of all fisher's data and does not disaggregate the gear types used. For a more concise view of catch composition and seasonality this has been reconstructed differentiating between gill net catch and trammel net catch as both nets have differing selectivity characteristics, which can influence seasonal representations of catch when dealt with indiscriminately. Despite this constraint to catch evaluation, Figure 6.1 confirms that the catch at USG is dominated by tilapia of varying size categories throughout the year. For this reason tilapia of differing size categories have been chosen as the focus of the following results in relation to fishing seasonality.

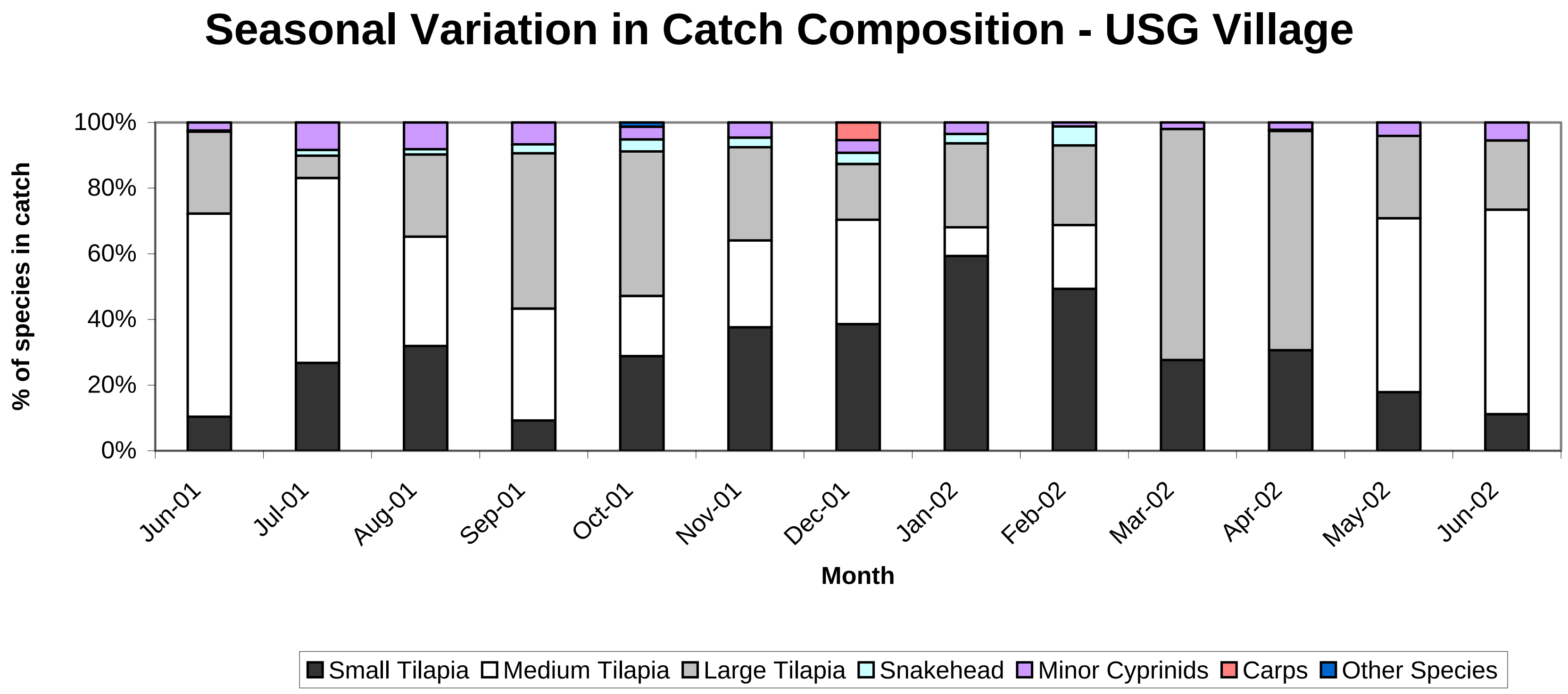

Figure 6.1 Seasonal variability in catch composition at USG village [1]

[1] Small tilapia = < 100g, Medium tilapia = ~150 – 250g, Large tilapia = >250g

Observations made at USG tank determined that gill net fishing was the most widely used method. The seasonality of tilapia catch composition for gill net fishers is presented in Figure 6.2. A further disaggregation of the data for specific gill net sizes and seasonality was not possible as fishers commonly fished with mixed mesh sizes which did not permit this analysis. Despite this constraint the figure shows that seasonality in gill net fishing is variable in terms of the catch composition achieved. Despite monitoring in August, no readings of CPUE for gill net fishers were recorded as most people undertook trammel net fishing at this period, possibly as a shift in effort to mitigate the impact of poor fish catches achieved in the previous month. Total CPUE increased in September but was followed by a gradual decline in CPUE until May.

The catch composition for gill net fishers is dominated by small tilapia, with the exception of October, November and June, where medium and large tilapia dominate the catch. Tank water spread area started in to increase in October to November from a period of relative stability and this may have accounted for the increase in CPUE of large and medium tilapia. A decrease in water spread area from May to June may also have accounted for the sudden change in catch composition and CPUE.

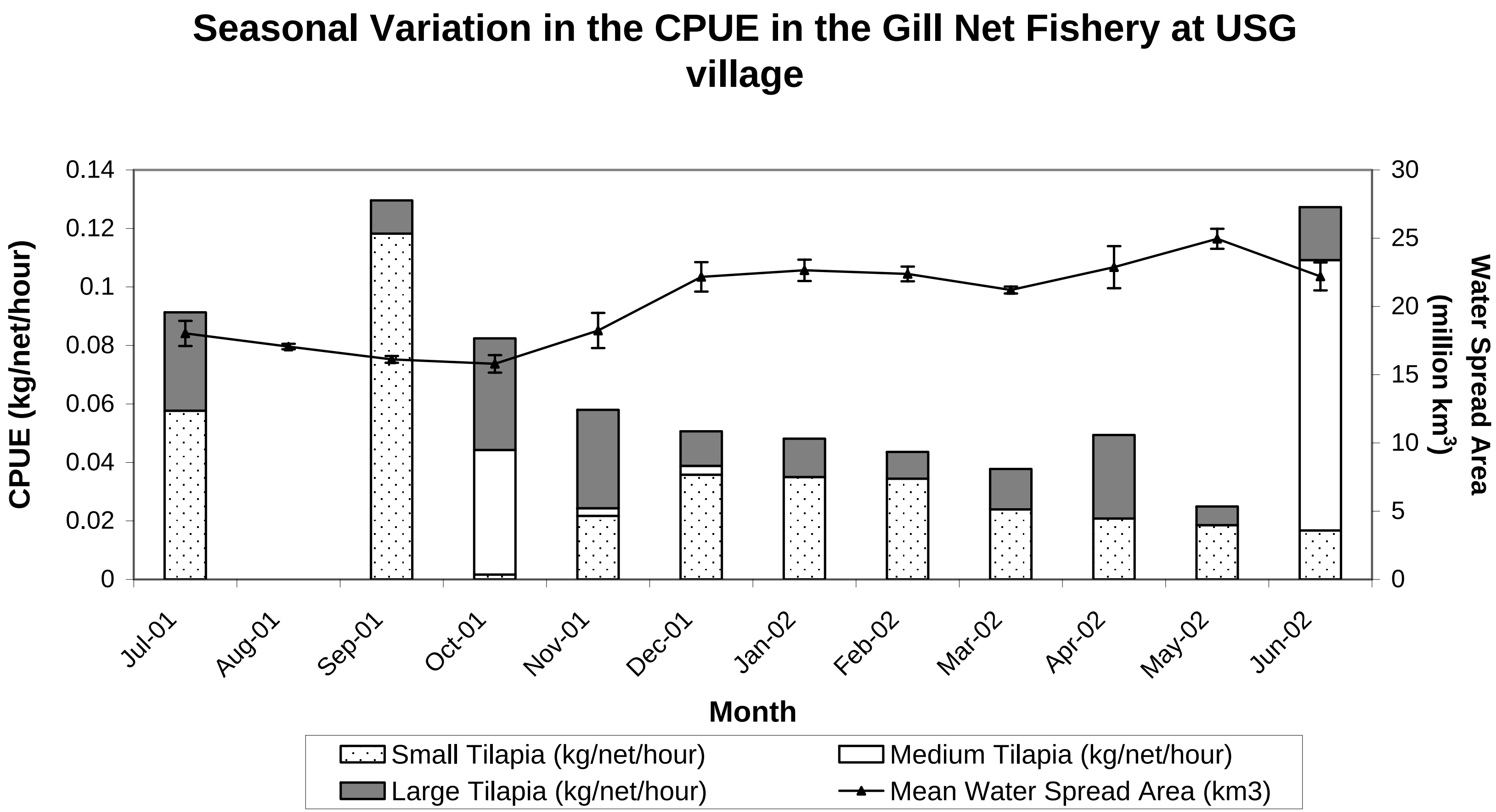

Figure 6.2 Seasonal variation of tilapia landings for the gill net fishery at USG village from July 2001 to June 2002

Total CPUE appears to mirror water spread area, increasing as the tank water level increases until the tank reaches its maximum level in May when fish catches are at their lowest for the year monitored. This suggests that fish catches increase in response to tank water level. This poses the question whether effort increases as a response to, or a pre-emptive attempt at negating, the effect of increasing water level on catch. This would be confirmed if water spread area and a variable of effort such as total number of nets used in the gill net fishery were related. This is considered later in the chapter.

The size categories of tilapia available in the catch change in response to water spread area. As water level begins to increase, the importance of large and medium size tilapia in November and December increases. After this initial phase, when the rate of increase for water spread area slows, the catches of large and medium tilapia decline and small tilapia become the predominant feature of the catch. A possible explanation would be that some fishermen increase fishing effort at this time by decreasing the size of mesh or increase the number of meshes deployed either to offset the decrease in CPUE or to exploit opportunity when CPUE is high. The seasonality of fishing effort is considered below.

6.3.4 Gill net fishing – seasonality and effort

Seasonal responses to water spread area and catch conditions were assessed by looking at the deployment of fishing gears and time spent fishing. This provided an account of seasonal variability in fishing intensity. An aggregated graph of mean gill number of gill nets deployed between October 2001 and March 2002 is depicted in Figure 6.3.

Gill net deployment time was also recorded. Although no obvious trend can be detected from Figure 6.3 alone, both measures of effort were examined statistically for both collective data and individual fishers' data using gill nets over the monitoring period.

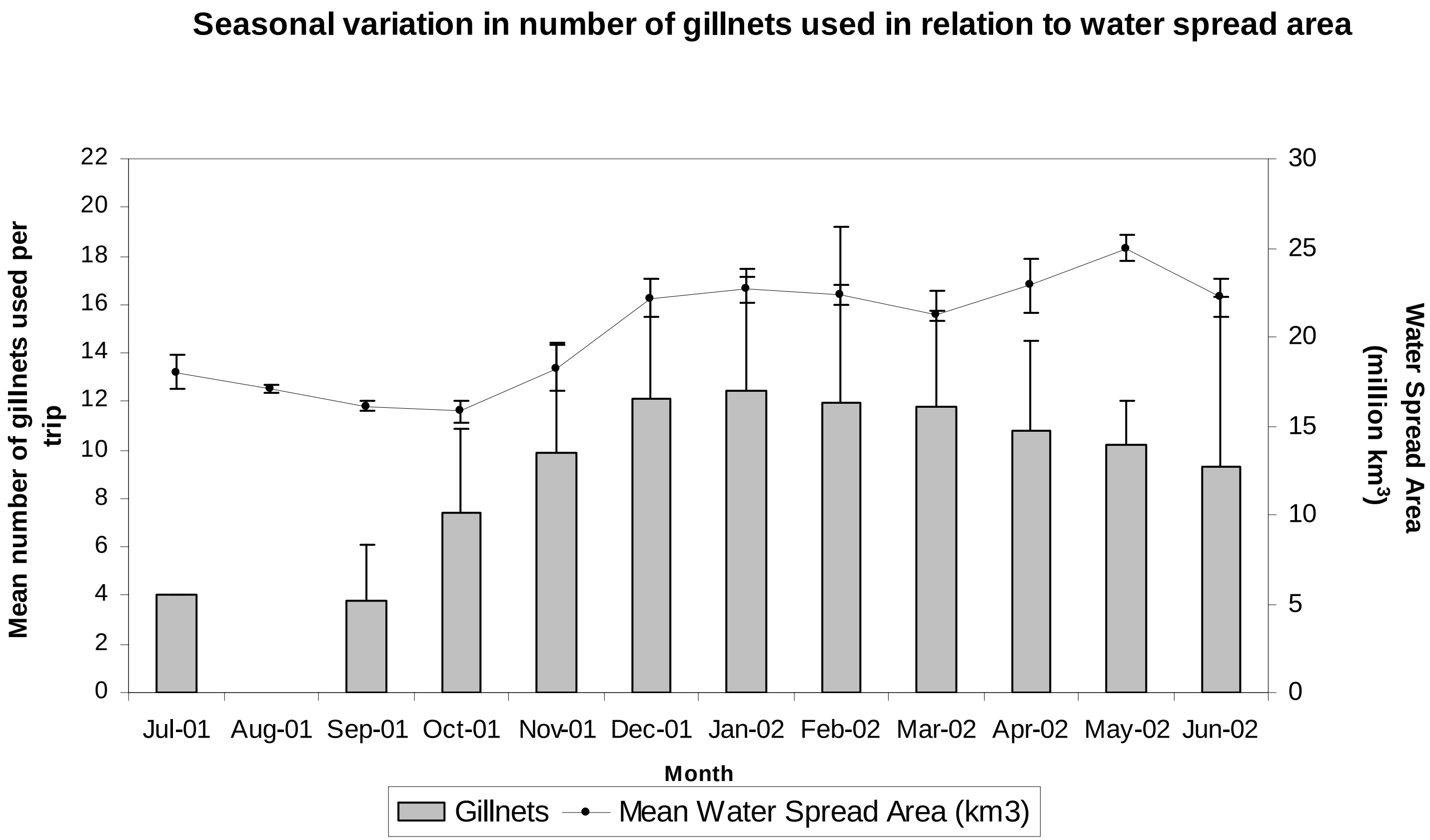

Figure 6.3 Seasonal variation in the number of gillnets used in relation to the water spread area at USG village

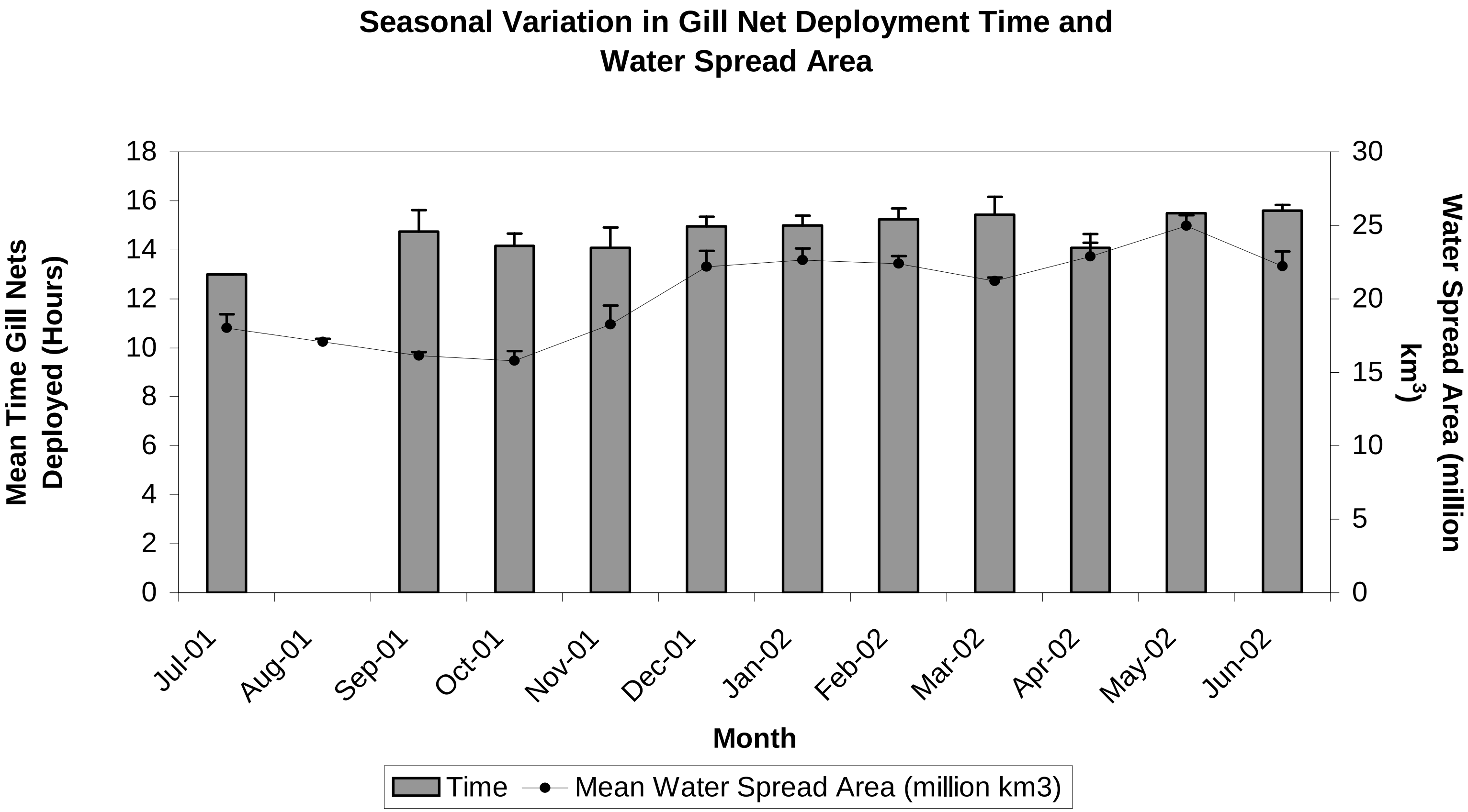

Figure 6.4 Mean gill net deployment time and water spread area, USG village

6.3.5 Statistical analyses – gill nets

Statistical analysis conducted using the Pearson's Partial Correlation, controlling for variability between respondents, was conducted to assess the key relationships within the fisheries data. The salient findings are presented and full data tables from all of the analyses are presented in Appendix 11.

Catch characteristics and water spread area

Water spread area and CPUE are significantly negatively correlated ($r = -0.456$, $n=95$, $p<0.01$). This indicates that as water spread area increases catches decrease. This confirms the findings of the situation appraisal with respect to fisheries characteristics in USG village. Whereas catches of small tilapia were not significantly correlated with water spread area, the CPUE of medium and large tilapia were both negatively correlated with water spread area ($r = -0.348$, $n=95$, $p<0.01$) and ($r=-0.274$, $n=95$, $p<0.01$) respectively. This indicates that as water spread area increases, catches of larger fish in the medium and large size categories decrease. There is a commonly held belief amongst fishers that as water spread area begins to increase at the onset of the *Maha* monsoon, larger fish are caught for around 2 – 4 weeks. After this time, catches decrease. This seems to be reflected in Figure 6.2 in October and November when catches shift from being dominated by small tilapia to be dominated by medium and large tilapia for this period.

Fishing effort and water spread area

As shown in the previous section, CPUE decreases as water spread area increases. This indicates that fishing is adversely affected by seasonality. Both the number of gill nets used and the total time nets are deployed are positively correlated with water spread area ($r = 0.398$, $n=95$, $p<0.01$) and ($r = 0.405$, $n=95$, $p<0.01$). This indicates that as CPUE decreases with water spread area, effort increases with the likely intention of mitigating income reductions associated with decreasing CPUE. This indicates that gill net fishers in USG employ adaptive strategies to cope with seasonal fluctuations in fish catches.

6.3.6 Trammel Net Fishery - Seasonality and Effort

Catching efficiency is increased by the “beating technique” previously described by Amarasinghe and Pitcher (1986) and in both villages was only found to be used when trammel nets were operated. Catches and catch composition obtained by trammel net use also demonstrated seasonal variation. This is depicted in Figure 6.5.

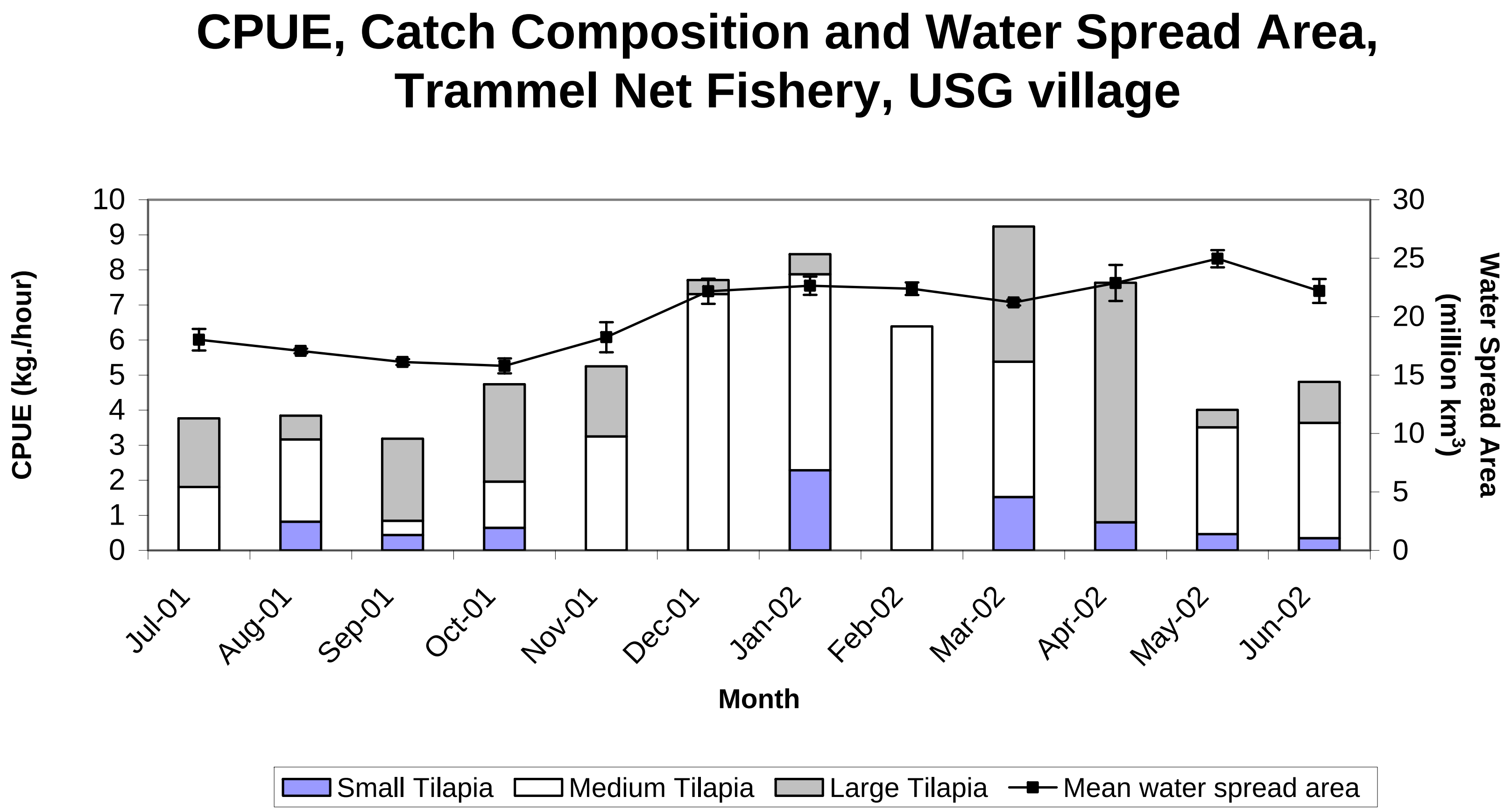

Figure 6.5 CPUE, Catch Composition and Water Spread Area in the Trammel Net Fishery at USG village

From Figure 6.5 it is apparent that trammel nets consistently catch more medium and large size tilapia which account for the greatest proportions of the catch. Although not presented in a comparative manner, CPUE in the trammel net fishery is higher than that of the gill net fishery.

There is greater seasonal variation in the gill net fishery than in the trammel net fishery, indicating that trammel nets seem more resilient to fishing seasonality.

6.3.7 Statistical Analyses – trammel nets

The results of Pearson's partial correlation, controlling for variability between fishers are presented below.

Catch characteristics and water spread area

The results of the analysis show that CPUE and water spread area are positively and significantly correlated ($r = 0.343$, $n = 88$, $p < 0.01$). CPUE of medium tilapia is positively and significantly correlated with water spread area ($r = 0.363$, $n = 88$, $p < 0.01$).

Fishing effort and water spread area

Fishing effort, measured as time spent active fishing using the beating technique, was negatively correlated with water spread area ($r = -0.560$, $n = 88$, $p < 0.01$). This may indicate that as CPUE increases with water spread area, fishers spend less time fishing using trammel nets as they are able to meet their household needs in the prevailing conditions. This may also indicate that at certain times of year, spending time actively fishing may be decreased due to other work commitments, such as during the cultivation season or poor weather conditions.

6.4 Results RAJ Case Study

6.4.1 Assets

An asset-based assessment of human, social and natural capitals is presented in. Table 6.9. This is disaggregated by respondent name and adopter category for clarity due to heterogeneity.

Human Capital

Although few households were studied those that adopted aquaculture were found to have marginally higher human capital than all other adopter categories. Their household sizes were 3.66 AEU which, with the exception of PAL, is greater than households in other adopter categories. Table 6.9 indicates that adopter households have marginally higher numbers of earners per household than the other adopter categories. This is due to the input of both male and female labour. Magdalene's son, working in Colombo, contributed remittances and THL's husband was a full-time fisher.

In households such as MCA, ARY and LAL, the female households members are educated more than the men. This is caused by a tendency amongst young men to leave school prior to O-level exams in order to take up fishing, whilst girls continue in their education.

Table 6.9 Human, social and natural capital of households in RAJ village

		Human Capital					Social Capital		Natural Capital	
Respondent Name	**Adopter status**	**Household size (AEU)**	**Number of earners in household**	**No. of household members educated > 15 years**	**Male Educated > 15 years**	**Female Educated > 15 years**	**No. of Society Memberships Held**	**Office Bearer Score**	**Paddy land value**	**Highland Land Value**
MAG	Adopter	3.66	3	2	1	1	5	2	0	0
THL	Adopter	3.66	2	0	0	0	6	1	0	0
MCA	Discontinuer	3.49	2	1	0	1	5	1	0	0
PAT	Discontinuer	2.56	1	0	0	0	3	1	0	0
ARY	Non-adopter	1.83	2	1	0	1	1	1	0	0
BER	Non-adopter	3.39	1	0	0	0	4	1	0	0
COS	Non-adopter	1.83	2	0	0	0	4	2	0	0
JSH	Non-adopter	2.33	1	2	1	1	3	1	0	0
MTH	Non-adopter	1.83	2	0	0	0	2	1	0	0
NEL	Non-adopter	2.56	1	2	1	1	1	1	0	0
RTH	Non-adopter	3.06	1	0	0	0	3	1	0	0
KMR	Non-adopter with cage	2.33	2	0	0	0	1	1	0	0
LAL	Non-adopter with cage	2.83	2	1	0	1	1	1	0	0
PAL	Non-adopter with cage	4.95	2	0	0	0	2	1	0	0

Social Capital

Table 6.9 shows that adopters are involved in more organisations and societies than other households. In particular female-headed households hold a greater number of organisational memberships than other households. This is perhaps due to the reduced importance of social self-help and development groups to the male-headed household where income levels are sufficiently sustained consequently reducing the relevance of building social support networks. For the female headed household, being part of a social network and involved in as many self-help group activities as possible is beneficial for food security and credit provision.

At RAJ village other strong social links not mentioned in Table 6.9 were maintained with other family members and friends in coastal areas. During lean fishing periods within the village or peak periods of activity at the coastal areas, some households migrated to the coast to exploit seasonal opportunities. Drawing on their social support networks facilitated migration of this sort.

Natural Capital

The lack of agricultural land of any type is a key characteristic of RAJ village, although this is compensated for by prime access to RAJ tank fishery. RAJ village is constructed on tank reservation land owned by the Irrigation Department. The community are officially deemed encroachers but since the construction of the camp, there have been no attempts made to remove the residences by the Irrigation Department. An offer of replacement homestead land within the traditional farming village nearby was made by the Irrigation Department, however most households chose to remain in close proximity to the tank for ease of access to the fishery. A small area of homestead land was owned by two of the households surveyed amounting to 0.1 hectares each. The area owned was valued at Rs. 20 000 by one household and Rs. 50 000 by the other. This was land was allocated by the government in an attempt to resettle the fishing camp encroachers. In addition, the construction costs of a new dwelling were a further limiting factor. Other than homestead land, there has been no provision of agricultural land for members of the fishing community and there is no crop cultivation.

The illegal nature of the RAJ village encroachment has led many of the villagers not to invest in more permanent housing and many of the households in the village are constructed of wattle and daub walls and cadjun roofing. There is still some belief in the community that one day they will be forcibly moved by the irrigation department although this has not been attempted through official channels since the first settlers arrived in 1968.

Physical Capital

The main income generating activity is fishing rather than agriculture, hence the main aspects of physical capital are related to this. There is no apparent pattern between adopter categories. Fishing asset values are highly variable across all households. The number of nets owned also varies and contributes to varying fishing asset values. Of key importance is the lack of ownership of fishing nets of one adopter (MAG) and one discontinuer (PAT). Although MAG had continued to fish for minor cyprinids from March onwards using a borrowed net, both herself and PAT's inability to fish for tilapia created problems for stocking their own cages. This led to PAT's discontinuance.

Table 6.10 Physical capital and adopter status in RAJ village

			Physical Capital		
Respondent Name	Gender	Adopter status	Value of Fishing Assets (Rs.)	Number of nets owned	Transport assets (Rs.)
MAG	F	Adopter	11000	0	24500
THL	F	Adopter	43200	16	18500
MCA	F	Discontinuer	36300	Shared with KMR	1200
PAT	F	Discontinuer	0	0	0
ARY	M	Non-adopter	44200	40	68500
BER	M	Non-adopter	13300	2	2000
COS	M	Non-adopter	30350	8	0
JSH	M	Non-adopter	31000	5	0
MTH	F	Non-adopter	9000	6	35000
NEL	M	Non-adopter	17200	12	42000
RTN	M	Non-adopter	17000	12	26000
KMR	M	Non-adopter with cage	27200	15	5000
LAL	M	Non-adopter with cage	26000	2	65000
PAL	M	Non-adopter with cage	65000	50	3000

Transport such as bicycles, and in some cases motorbikes, was found in the majority of households. Where the values are high a motorbike was the main asset. PAT (a poor female head of household) and JSH did not have bicycles. They depended on neighbours for bicycle use although more often than not would reach places such as the junction shops and school on foot. COS did not own a bicycle due to a combination of old age and poor health. Despite his lack of access to his own transport, his relatives lived nearby and could run errands for him for medication or take him to medical facilities using their motorbikes. In this case his social network provided compensation for his lack of physical capital.

Financial Capital

Table 6.11 indicates no apparent relationship between the types of financial capital of a household and their adopter status. Most households, with the exception of PAT, hold a considerable amount of savings in gold jewellery that can readily be liquidated in times of economic hardship. The richest householder in the group in income terms (PAL) held proportionally less jewellery and a moderate amount of savings that perhaps indicated he placed greater value on the accumulation of other assets. His house was the most permanent of residences within the community being constructed of brick and had a tiled roof. His family size was also greater which may indicate that the proportion of his income spent on consumption was greater than other households with fewer children.

Livestock holdings varied between a few chicks demonstrated by PAT to goats (MAG) and cattle (JSH, RTH and KMR). Women preferred to keep smaller animals such as chickens and goats as they were easier to manage than cattle. A goat-breeding programme was being implemented in the village for women at the time of monitoring.

Access to credit was possible for all households with the exception of PAT. Borrowings were made from both financial institutions in Thambuttegama for items such as fishing nets, but also from moneylenders within the village. PAL was a known moneylender, although he never declared any income from this source to enumerators. The local shop provided goods on credit. Household monitoring identified that poorer households such as PAT and MAG were charged more for items such as bread and eggs than better off households.

Table 6.11 shows that people wealthier in income terms do not borrow money or borrow less than other households. Some households appear to manage without either saving or borrowing. MTH's household is an example of this behaviour.

Table 6.11 Financial Capital and Adopter Status, RAJ Village

		Financial Capital					
Respondent Name	**Adopter status**	**Value of Jewellery (Rs.)**	**Total Livestock Value (Rs.)**	**Savings deposited in past year (Rs.)**	**Total cash borrowed in past year (Rs.)**	**Total Annual Income (Rs.)**	**Income rank[1]**
MAG	Adopter	14000	10000	7750	21000	73009	13
THL	Adopter	3500	0	2400	15000	130459	8
MCA	Discontinuer	35000	6000	0	10000	193040	3
PAT	Discontinuer	0	50	0	10000	19900	14
ARY	Non-adopter	15000	0	2000	10000	134685	6
BER	Non-adopter	4500	600	7000	0	119410	9
COS	Non-adopter	1500	1400	4040	15000	99709	10
JSH	Non-adopter	12000	8000	1800	3000	74151	11
MTH	Non-adopter	20000	0	0	0	75598	12
NEL	Non-adopter	10000	0	1000	0	177522	4
RTH	Non-adopter	9000	22800	150	3000	139502	5
KMR	Non-adopter with cage	12000	12000	11000	0	230240	2
LAL	Non-adopter with cage	25000	0	2000	3000	147084	7
PAL	Non-adopter with cage	6000	220	7000	0	295553	1

[1] Income rank is indicative relative income status within the group based on the total annual income (Rs.) of the respondents (1 = highest income, 14= lowest income)

The degree to which a household is diversified in its livelihood strategy is also an indicator of household vulnerability. Table 6.11 indicates household income from different sources and their relative contribution to total household income per annum is presented in Table 6.12. The majority of the households in RAJ rely on fishing as their principal income source, with little diversification into other livelihood activities.

The tables indicate that households that derive a smaller percentage of their household's income from fishing have a larger income from fish drying. The reason for this is that women can purchase small tilapia or minor cyprinids and dry them which means that they can operate independently. Fish drying is practiced as a collective activity by women with salt purchased in bulk to reduce individual costs. COS was restricted in his fishing capabilities owing to his old age and poor health. His catch principally comprised of minor cyprinids and small tilapia caught in the inshore area of the tank. His income from fishing was consequently less than other fishing households and a considerable amount of his catch was dried.

PAT was the only householder who engaged in wage labour. Her labour earnings were derived from agricultural labour in the nearby farming village. This was mainly restricted to harvesting periods. She also generated other income within the village by removing fish from nets in peak times when high volumes of fish were landed. In some cases she received cash earnings but payment was also received in kind in the form of fish for home consumption. This was her principal means of income although she was heavily dependent on state benefits. Her discontinuance of cage culture was partly due to her labour time, but also that she had childcare responsibilities as her daughter had migrated to the Middle East and left her with three young children.

Table 6.12 Total household income (Rs./annum) and percentage income derived from livelihood activities, RAJ village

Respondent Name	Adopter Status	% Fishing	% Fish Drying	% Wage Labour	% Middle East Remittance	% Other Remittance	% State Benefits	% Other Income Sources	Total Annual Income (Rs.)
MAG	Adopter	15	53	0	0	33	0	0	73009
THL	Adopter	84	9	0	0	0	6	0	130459
MCA	Discontinuer	66	34	0	0	0	0	0	193040
PAT	Discontinuer	0	0	8	0	0	42	50	19900
ARY	Non-Adopter	88	9	0	0	0	0	3	134685
BER	Non-Adopter	91	2	0	0	0	7	0	119410
COS	Non-Adopter	59	22	0	0	0	4	16	99709
JSH	Non-Adopter	94	6	0	0	0	0	0	74151
MTH	Non-Adopter	67	33	0	0	0	0	0	75598
NEL	Non-Adopter	100	0	0	0	0	0	0	177522
RTH	Non-Adopter	92	8	0	0	0	0	0	139502
KMR	Non-Adopter with Cage	90	0	0	10	0	0	0	230240
LAL	Non-Adopter with Cage	98	2	0	0	0	0	0	147084
PAL	Non-Adopter with Cage	96	1	0	0	0	3	0	295553

Fishing assets

As fishing is the principal income source an examination of fishing assets is presented in Table 6.13.

The table highlights that the non-adopters with fish cages derive the highest proportion of their income from fishing. The top two earners in the village are located within the group of non-adopters with fish cages. This indicates that their income levels are so large from a single activity that they perhaps feel no need to diversify into a small-scale activity such as cage-based fattening. PAL has invested the greatest amount in fishing gear and consequently derives a greater income from fishing than other households.

Of the discontinuing households, MCA although she has a moderate income from fishing was dependent on her son to stock cages based on his catch. This caused a disagreement with her son as he did not feel that the cage was an important focus of household income generation. Her discontinuance was influenced by her lack of support within the family and consequent lack of access to fish for stocking. PAT had no income from fishing and no fishing assets of her own with which to catch fish. This, in addition to her labour and childcare constraints, meant that she discontinued.

Table 6.13 Household fishing assets and adopter status, RAJ village

Respondent Name	Adopter Status	Total Income from Fishing (Rs./annum)	% Income from Fishing	Value of Fishing Assets (Rs.)	Total Number of Nets Owned	Type of Boat Owned	Access to Boat
MAG	Adopter	10609	15	0	0	No boat	Yes
THL	Adopter	109559	84	43200	16	Fibreglass	-
MCA	Discontinuer	128200	66	36300	15	Fibreglass	-
PAT	Discontinuer	0	0	0	0	No boat	Yes
ARY	Non-adopter	118685	88	44200	40	Fibreglass	-
BER	Non-adopter	108610	91	13300	2	Fibreglass	-
COS	Non-adopter	58429	59	30350	8	Fibreglass	-
JSH	Non-adopter	69351	94	31000	5	Fibreglass	-
MTH	Non-adopter	50598	67	9000	6	Fibreglass	-
NEL	Non-adopter	177522	100	17200	12	Fibreglass	-
RTH	Non-adopter	128222	92	17000	12	Fibreglass	-
KMR	Non-adopter with cage	206240	90	27200	15	Fibreglass	-
LAL	Non-adopter with cage	143484	98	26000	2[1]	Fibreglass	-
PAL	Non-adopter with cage	283553	96	65000	50	Fibreglass	-

[1] Although LAL only declared 2 fishing nets, he uses his fishing partner's nets. His partner was not included in the household survey group. He also spends much of his fishing time using trammel nets rather than gill nets.

6.4.2 Seasonality

In RAJ, the tank fishery is the principal income source for most of the households studied, therefore seasonality of fishing income and seasonal changes in fishing behaviour are the focus of the following section.

Table 6.14 shows that irrespective of adopter status, income from fishing varies from month to month.

Table 6.14 Seasonal Variation in Mean Monthly Income from Fishing and Adopter Status

Respondent Name	**MAG**	**THL**	**MCA**	**PAT**	**ARY**	**BER**	**COS**	**JSH**	**MTH**	**NEL**	**RTH**	**KMR**	**LAL**	**PAL**
Interview Date	Adopters		Discontinuers		Non -Adopters							Non-Adopters With Cages		
Oct-01	- [1]	4650	12263	0	-	-	-	-	2250	20925	11935	-	12555	12150
Nov-01	-	5822	11798	0	15694	14850	2025	-	2250	17100	14700	13716	6413	40950
Dec-01	-	11160	5018	0	10288	7808	465	3294	1395	11644	5813	14144	11231	22785
Jan-02	-	16411	9300	0	6452	2480	6258	8008	5115	6898	13950	21429	16740	10308
Feb-02	-	5240	3990	0	3185	5985	4200	4480	2520	10080	- [2]	22365	6580	17325
Mar-02	540	2829	14325	0	17825	11044	5231	5719	3953	18523	4960	17941	6975	24645
Apr-02	956	2625	3000	0	6000	12375	3750	5756	3600	10463	12750	4875	16275	12975
May-02	465	10191	13885	0	7304	9765	9823	5735	5900	10773	10424	13950	8913	23328
Jun-02	1575	14113	11888	0	12375	8100	7200	7463	6750	11944	10950	11888	9975	24570

[1] Respondent couldn’t be located for interview
[2] Migrated to coast for seasonal fishing activities

6.4.3 Catch characteristics and water spread area

The mean CPUE and catch composition of the gill net fishery are plotted in Figure 6.6. This figure shows that overall gill net fishers in RAJ village appeared to catch few small tilapia during the monitoring period. This is a major constraint to availability of small tilapia for stocking in cages. The catch is consistently dominated by medium and large tilapia. The total CPUE increased as water levels increased between October 2001 and January 2002. However, total CPUE decreased sharply once high water levels are established after January 2002 and there is a sharp decrease in total CPUE in February 2002. At this time small tilapia re-emerges in the catch alongside that of large tilapia. This may indicate that some fishers begin to fish for small tilapia as an emergency measure as overall catches began to decrease. At this point, however, CPUE peaks in March despite their being no notable increase in tank water spread area. This conflicts with findings in the situation appraisal which indicate that the highest catches are obtained when the tank water levels begin to increase.

The fact that the gill net catch is dominated by large tilapia may negate the need for participants to engage in a fattening system. This may explain why some male fishers with cages failed to fabricate and install their cages as fishing conditions and consequent drops in income levels were not enough to drive them into a decision to adopt.

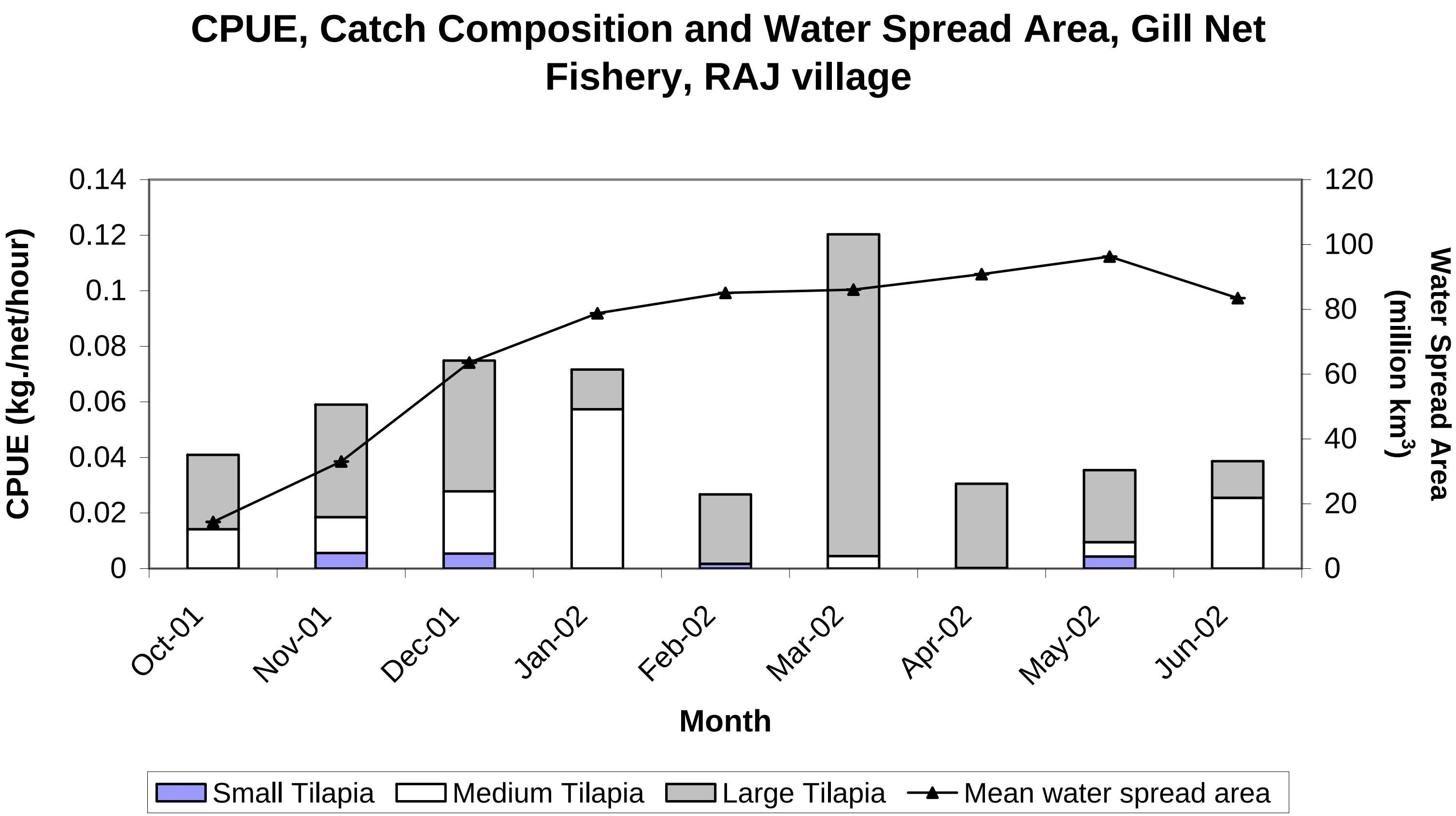

Figure 6.6 CPUE, Catch Composition and Water Spread Area in the Gill Net Fishery, RAJ village.

6.4.4 Gill net fishing – seasonality and effort

The seasonal variation in the number of gill nets used in relation to water spread areas is presented in Figure 6.7. This figure indicates that fishing the number of gill nets deployed seems to adapt in relation to water spread area which was blamed during the situation appraisal for affecting incomes from fishing by fishers during the situation appraisal. Fig. 6.7 supports this conjecture as the number of gill nets deployed appears to be increasing in response to increasing water spread areas as the tank fills during the *maha* monsoon season. For the majority of respondents (other than those using trammel nets) lower catches in December appear to have stimulated this response.

Fishing time was also considered indicative of fishing effort. Figure 6.8 plots water spread area and the number of hours for which gill nets were deployed. There does not appear to be a great variation in fishing time from month to month and therefore no relationship seems evident from the graph alone. Further statistical analysis on both of these points is presented below.

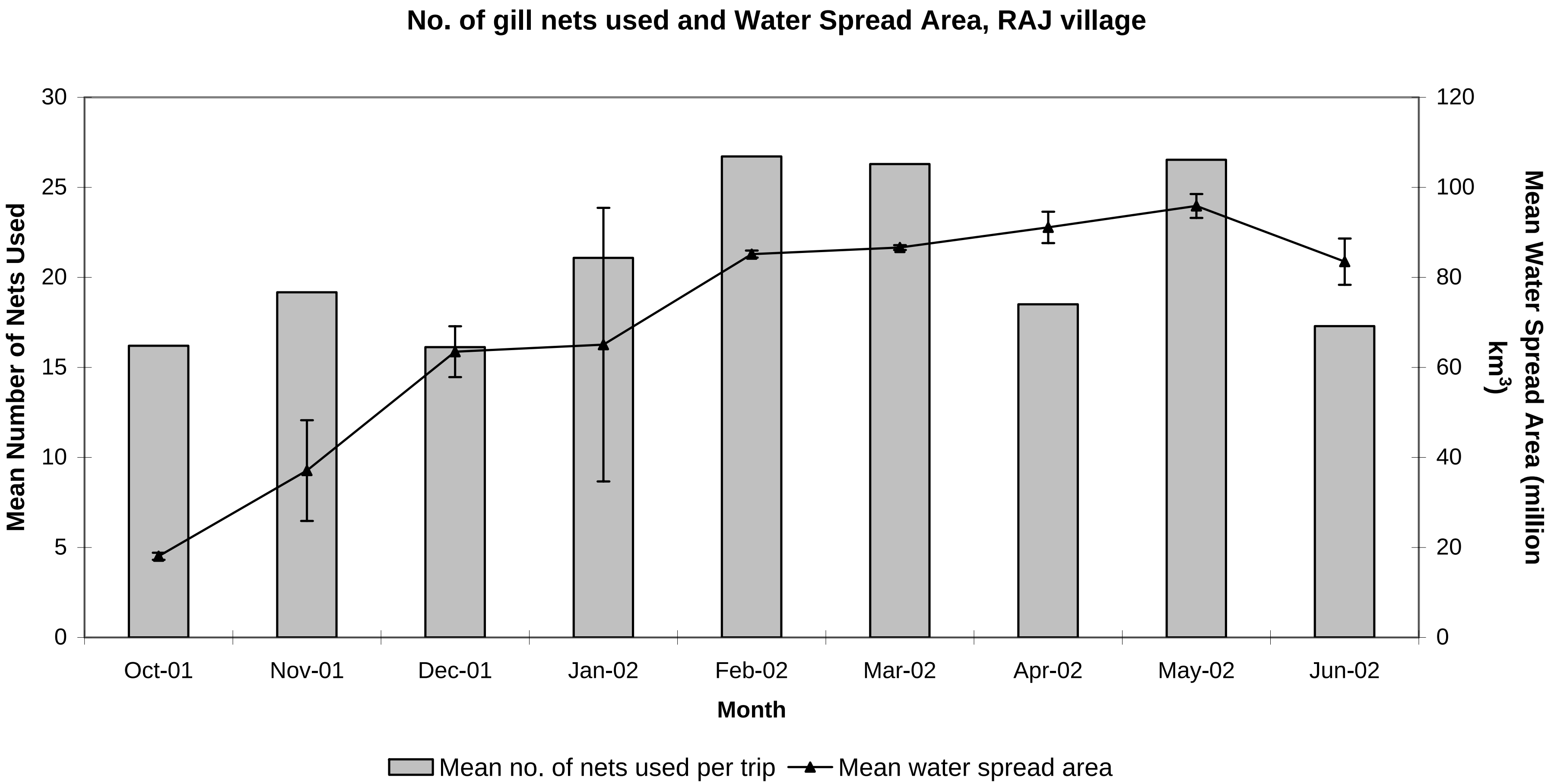

Figure 6.7 Seasonal relationship between number of fishing nets used per trip and mean water spread area at RAJ village.

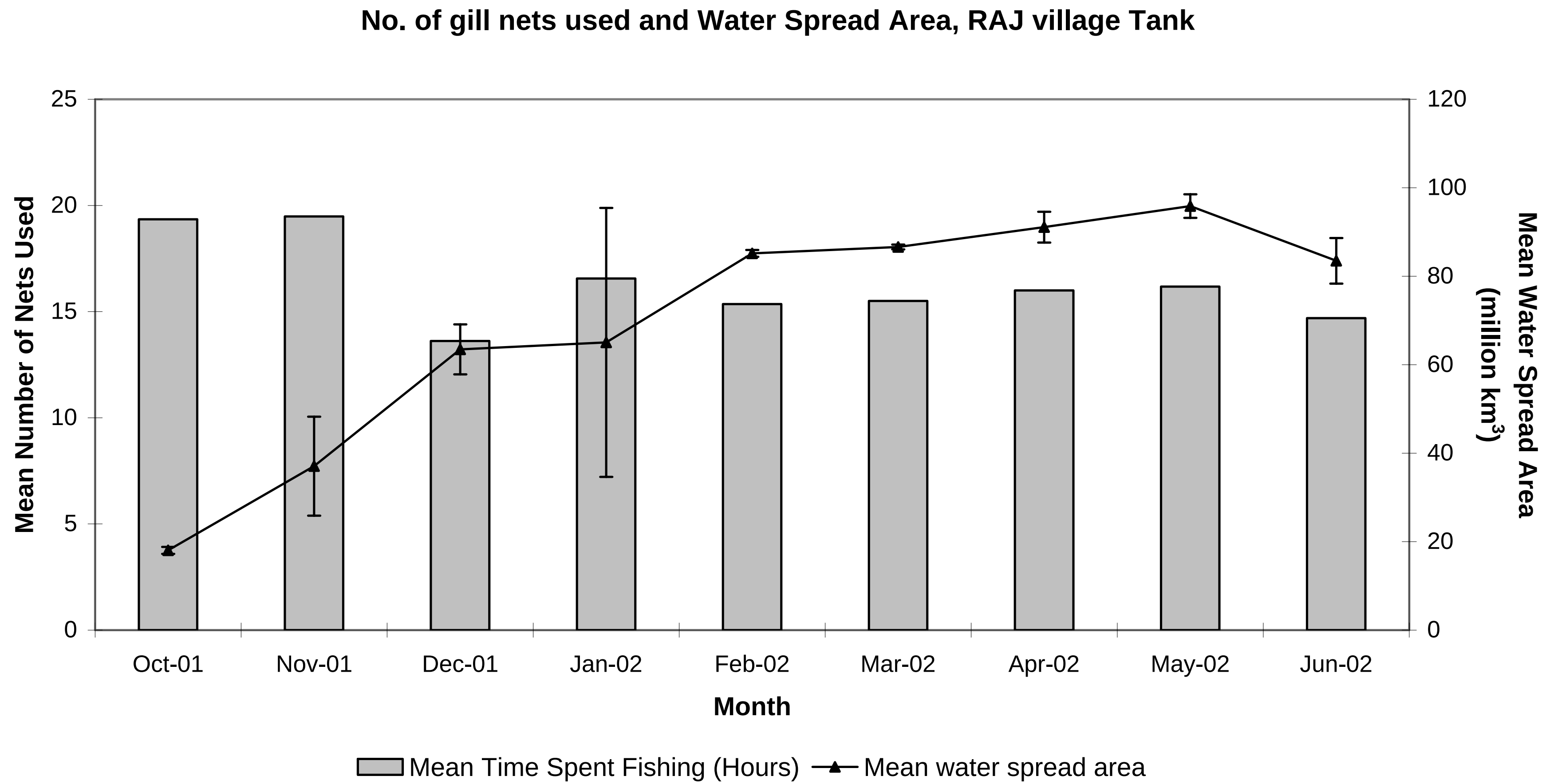

Figure 6.8 Seasonal relationship between mean time passive fishing and mean water spread area in the gill net fishery at RAJ village.

6.4.5 Statistical analyses

Statistical analysis conducted using Pearson's Partial Correlation, controlling for variability between respondents was conducted to assess the key relationships within the fisheries data. The most relevant findings are presented. Full data tables from all of the forthcoming analyses are presented separately in Appendix 11.

Catch characteristics and water spread area

Total CPUE, CPUE of medium and large tilapia were found to be negatively correlated with water spread area, however, none of these relationships were significant. This is most likely explained by low catches in the months of February, May and June (see Figure 6.6).

Fishing effort and water spread area

The number of nets used was positively and significantly correlated with water spread area ($r = 0.239$, $n=138$, $p<0.01$) which indicates that as water spread area increases and CPUE effort decreases, the number of nets increases in an attempt to offset this trend. Time spent fishing and water spread area were found to be significantly negatively correlated ($r = -0.229$, $n = 138$, $p< 0.01$). This may be accounted for not so much by catch characteristics but by the other demands on labour time and perhaps by poor fishing conditions. A division of labour between gill net fishing and trammel net fishing (where catches of small and large tilapia are high at this period) may provide some further rationale for this strategy.

6.4.6 Catch characteristics and water spread area - trammel net fishery

The seasonal variation in catch composition in relation to water spread area is presented in Figure 6.9. The graph shows that the CPUE for trammel nets remains relatively stable over the months monitored, irrespective of increasing water spread area. The catch composition demonstrates that very few small tilapia are caught using this method which is a major constraint to the availability of, and perceived need for, stocking fish in cages to fatten.

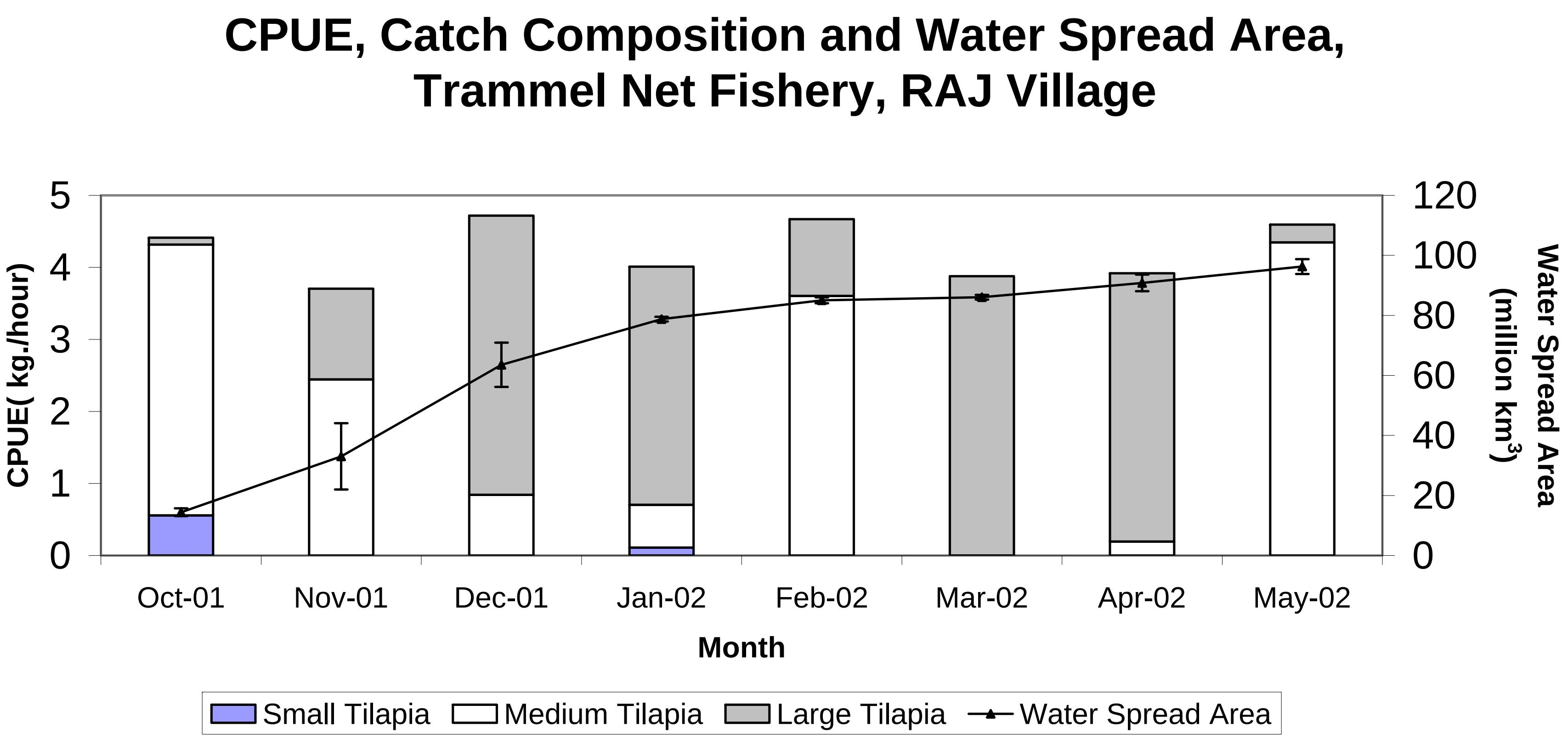

Figure 6.9 CPUE, Catch Composition and Water Spread Area in the Trammel Net Fishery, RAJ village

6.4.7 Effort in the trammel net fishery, RAJ village

The time spent actively fishing using the beating technique was used to measure if fishing time correlated with increasing water spread area. This indicated if effort changed in response to prevailing tank capacity conditions. Figure 6.10 plots the mean time spent fishing per trip for trammel net fishers in relation to water spread area in RAJ tank.

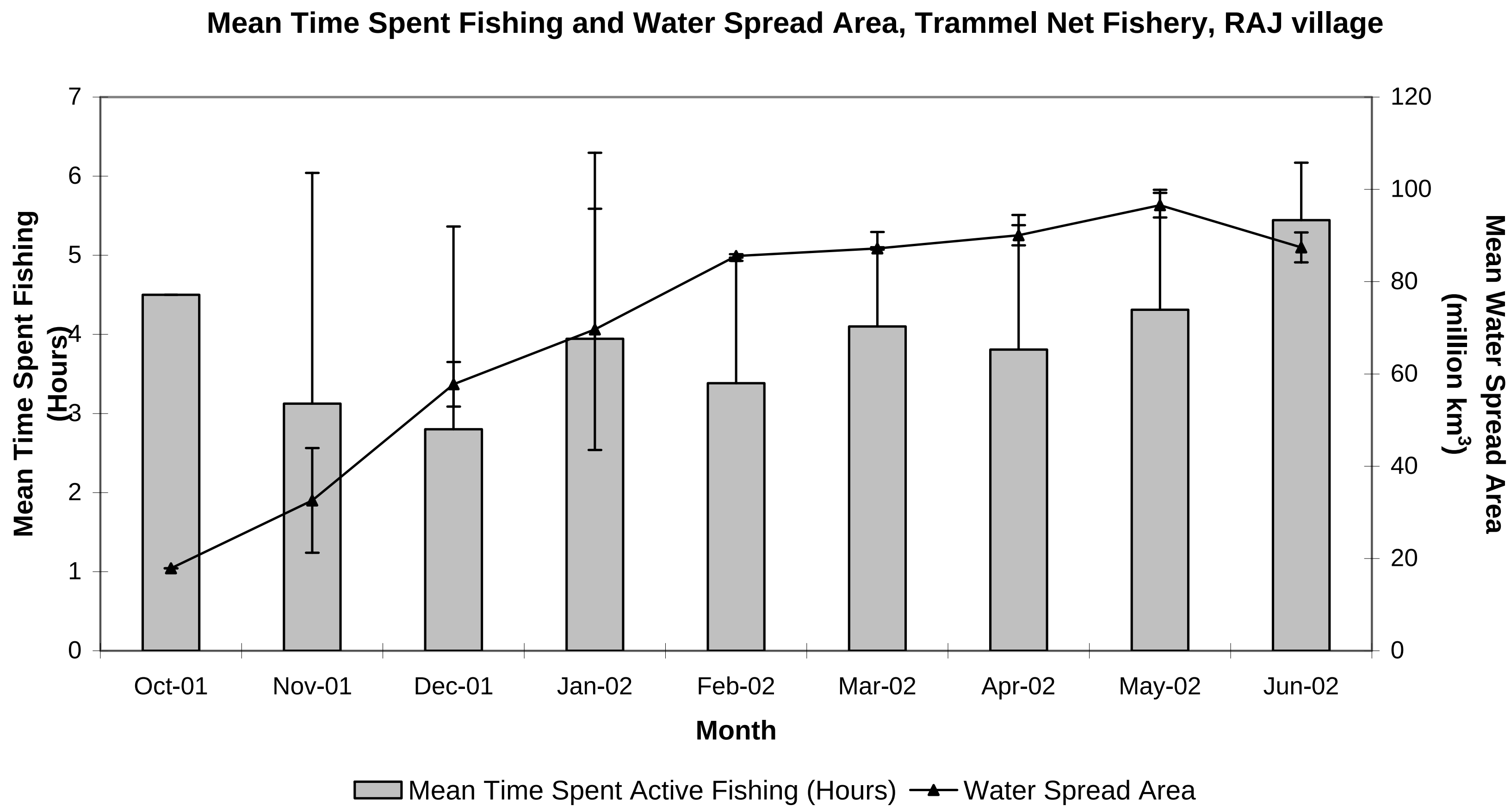

Figure 6.10 Seasonality of fishing time in relation to water spread area, trammel net fishery, RAJ village

6.4.8 Statistical analyses

The summarised results of the statistical analysis are presented below. The data collected was analysed using Pearson's partial correlation controlling for the effect of individual fishers.

Catch characteristics and seasonality

The analysis found that total CPUE and water spread area are significantly and negatively correlated ($r = -0.295$, $n = 74$, $p < 0.01$). Partial correlation analysis also found that the CPUE small and CPUE medium tilapia were negatively and significantly correlated with water spread area, ($r = -0.424$, $n=74$, $p<0.01$ and $r= -0.227$, $n=74$, $p<0.01$) indicating that as water spread area increases, the CPUE of these two size categories decreases. This is likely to be due to increasing relevance of large tilapia in the catch in Dec 2001, January, March and April 2002, however, a statistical relationship for CPUE of large tilapia could not be established.

Fishing effort and seasonality

No significant correlation between the time spent active fishing using the beating technique and water spread area was established, although a weak negative correlation was observed. This may indicate that a standard time period is employed when using a trammel net, irrespective of seasonal catch or weather conditions.

6.5 Discussion

The results presented indicate that the household livelihoods of adopters, non-adopters and discontinuers are varied and inconclusive in terms of generalising their characteristics. The findings demonstrate that fishing plays a dominant role in household income generation in USG and particularly in RAJ, being the prime source of day-to-day earnings. An exception to this was two female-headed households in RAJ (MAG and PAT), although they were indirectly involved in fishing through their assistance with removing fish from nets. The results show that fishing is seasonal and that catches landed by gill net and trammel net differ considerably. A key finding was that trammel nets consistently catch larger fish than gill nets although they are currently banned. Catches in USG gill net fishery were also more dependent on small tilapia than at RAJ.

Begossi (1998) indicates that fisheries management policy ought to account for the human behaviour aspect rather than assume that all members of a community will be homogeneous in their compliance with regulations. The work adds depth to the overall knowledge of Sri Lankan fisheries by taking into account the dimension of human behaviour. To date little work on the behaviour of fishers has been taken into account either within research of Sri Lankan fisheries or incorporated within the policy planning process.

6.5.1 USG– adopter status and livelihoods

Assessing human capital between households revealed no real differences in household size (AEU) between groups. However, the importance of educational status of women was an interesting finding as it became apparent that in some households, particularly young couples, women had gained higher educational attainment than young men. This suggests than men left school earlier to undertake fishing. Overall literacy was high and general health of the individuals good enough to continue in their livelihood activities without any constraint in this respect.

Social capital was measured in terms of the number of society memberships held by the respondents and office bearing positions within these societies regarded as indicative of greater social capital than ordinary member. In this respect, two of the four adopters in USG (GNE and WAN) were office bearers of the fisherman's co-operative society. Although the small sample size constrained any attempt to draw generalisations, the study indicated that those with higher social capital were more likely to try or adopt new technologies, in line with the thinking of Rogers (2003).

The relevance of natural capital was largely restricted to the access to the fishery. Access to the tank was equal for all respondents, however boat access was important to enable exploitation of the fishery. As all of the households surveyed in USG were boat owners, the issue of access was not a significant concern. A key point to note is that all of the adopters in USG lived in close proximity to a landing site (within 100 -200metres) which may have influenced their capacity to sustain the activity. Proximity to cages was noted as an important influential factor in cage sustainability (Brugere & Kaleda, 1999) and is perhaps one factor which enticed those particular members to sustain adoption over several months.

No distinct pattern between adopters and non-adopters was noted in terms of financial capital. The fact that the cage operation was low cost and perhaps was not interesting in terms of its financial rewards may have deterred some respondents from undertaking the activity. Household income from farming was variable and related to the amount of land cultivated. It is clear that land fragmentation has had an impact by reducing the proportion of household income which derives from farming. A key finding was the importance of Middle East remittances to the incomes of some households. Despite the increasing importance of these remittances, changes in fishing income were not observed which indicates that even the introduction of alternative income streams did not reduce dependency on the fishery for day to day cash.

Physical capital mainly focused on the assets and savings that households had accumulated. Overall there was great variability in the income generated and means of saving. No apparent pattern was established to suggest that adopters were inherently savers with a particular mentality in this respect predisposing them to ‘save’ fish in a cage as an alternative form of liquid savings. Likewise, no pattern was established to suggest that adopters were wealthier than non-adopters and more able to offset the risks involved in undertaking an unproven activity. In fact, it is more likely the case that cage aquaculture was not economically attractive enough for non-adopters to divert their labour away from their other activities, i.e. the opportunity costs involved were too high. This is particularly the case where the activity is incompatible with existing livelihood activities.

Fishing incomes were highly variable and the number of gears owned also varied between households. As fishing was the most important income source for all USG households, further analysis was undertaken to establish the extent to which households were affected by vulnerability. The findings confirmed that fishing was indeed seasonal in nature, which increased household vulnerability by affecting incomes. Furthermore, the results of correlation analysis show that fishers adapted to negative trends by increasing the time over which gill nets were deployed and the number of nets which were deployed per fishing period. This highlights the adaptive nature of fishing.

Fishers using trammel nets experienced higher catches as water spread area increased. A critical constraint to entry was that trammel net fishing is a more active method, requiring two relatively fit partners. In this case old fishers may not have benefited from the higher catches and large fish caught using this method and were therefore condemned to fish using traditional gill nets.

A possible strategy for younger fitter fishers would be the ability to switch methods; using gill nets until CPUE deceased with increasing water spread, shifting to trammel net fishing as water spread area increased.

The implications of the use of prohibited trammel nets and the policy implications are further discussed in Chapter 7.

Although catches of small tilapia dominated the gill net fishery, catches remained quite low for most of the year for gill netters and trammel netters caught predominantly medium and large tilapia. Therefore, this examination of the fishery complements and verifies the constraints to cage adoption identified in Chapter 5.

Why did some fishers in USG adopt?

It is most likely that adopters at USG did so as they viewed the activity as highly compatible with their existing income generating activities. Their close proximity to the tank may have assisted in this. In the cases of GNE and WAN their experiences with livestock keeping, their close proximity to the tank and potential to augment their social status through entrepreneurship and progressiveness may have been at the heart of their decisions to adopt. In the case of MBA a system of holding and fattening tilapia to a larger market size was highly compatible with his existing forays into fish vending on a seasonal basis. NAN on the other hand, perhaps viewed the concept as highly compatible with his needs. The fact that his wife was sending remittances from the Middle East may have decreased financial pressure on him and given him the capacity to take a risk and try something new. He was also no stranger to diversification keeping a considerable number of goats. These case studies all point to the importance of individual circumstances and therefore one may conclude that generalisations of a household's likelihood to adopt cannot be taken on income or broader livelihoods information alone. Personality variables and more importantly perception of benefits must also be considered.

Why didn't some fishers adopt?

Other income generating activities were a key feature of all households in USG. The discontinuer, WIJ, stopped cage culture as he did not have enough small tilapia to stock. All respondents cited lack of fish for stocking in Chapter 5 during the scoring exercise. The statistical analysis has shown that fishers use more gill nets and fish for longer to mitigate the seasonality of fishing. This, however, does not appear to be reflected in individual household incomes from fishing in Table 6.7. Despite this statistical finding, non-adopting households may have felt that their fishing strategy for coping with seasonal income fluctuations negated a further need for an activity such as cage-based fattening of tilapia i.e. the perception of relative advantage of the system was low. Lack of time for engaging in cage based fattening of tilapia may also have been a factor. For example WML undertook numerous income generating activities which he had to manage. AJN looked after a herd of buffalo which also provided him with a steady and seasonally resilient daily income from milk sales. SUR was able to find enough work undertaking labour (principally timber sawing and masonry) in addition to fishing. SIM managed to derive a higher proportion of his income from farming than the others and therefore may have not perceived a need to seek out new opportunities.

Rogers (1995) states that secondary adopters often adopt on the basis of initial adopters' successes. The experiences of the initial adopters in this case produced black fish and these observations in terms of their colouration and lower consumer preference may have contributed to their decision not to adopt.

6.5.2 RAJ– adopter status and livelihoods

At RAJ heterogeneity within the adopter and non-adopter groups was also observed. Therefore any analysis intended to demonstrate significant differences between groups was nullified. The investigation did serve to further knowledge of the context in which adoption was more or less likely to occur by gaining a greater understanding of household livelihood strategies. A key finding was that fishing represented a far greater proportion of income for most households than in USG (with the exception of female headed households). In addition to this male fishing households seemed to specialise in fishing by apportioning larger amount income into the accumulation of fishing assets. The number of nets, although variable between households was higher than that of fishers at USG village. This could be expected as fishing at RAJ is the sole income generating activity for most households, with the exception of female-headed households where fishing was not undertaken and livelihoods were far more diversified.

Why did women adopt?

Social capital played an important role for women in RAJ village. They had greater participation in numerous societies and organisations compared to men whose organisational membership was only in the fisheries society. Female-headed households apportioned great importance to participation in society meetings and valued social connectedness. In times of need their social networks are drawn upon to survive. Collectively membership of groups such as SEDEK and PRDP (North Central Province Participatory Development Project) has enabled them to access credit and to begin accruing assets in the form of savings and livestock. Women's groups show great internal solidarity but their motive for joint action is largely driven by moral economy considerations, that is the desire to protect or enhance traditional values (Hyden, 2001). This view seems to be the case in RAJ as the group was involved in savings schemes and low - level income generating activities to help each other. This contact with 'outsiders' and collective action may have increased women's confidence to attempt something new as this had previously been the case with the introduction of goat farming within the village. As cage-based fattening of tilapia was introduced through group meetings, women may have identified with this activity in that forum and decided to participate for that reason. It is also likely, however, that women felt cage culture was highly compatible with them as they could obtain trash fish for feed as they were either involved in removing it from nets (PAT and MAG) or could obtain it from their husbands

(THL). The perception that they could obtain fish for stocking from either male family members or friends perhaps assisted their decision to adopt.

Why didn't fishermen adopt?

After examining the income and livelihoods characteristics of the other households in RAJ it is fair to say that the income levels accrued through fishing in most households were high enough to assume that diversification was not viewed as a necessity. In this village most households operated their livelihood strategy of specialisation rather than diversification. This is in direct contrast to the case of MAG, a female-headed household adopter, who was pushed into diversification through necessity rather than choice (Ellis, 2000). For fishermen (with the exception of COS) specialisation had led to higher incomes that meant there was no perceived need to diversify. The opportunity cost of participation in cage-based fattening in the prevailing fishing conditions may have been too high to facilitate adoption in this group. In addition to this fishing studies also showed that the catches of small tilapia were small in comparison to USG village. If fishers were more accustomed to catching medium and large tilapia in any case and seasonality of fishing was mitigated to a satisfactory level by increasing gear numbers or undertaking trammel net fishing, then the perceived need for a system used to obtain larger fish would have been small in the prevailing context.

6.5.3 Fisher behaviour and fishing strategies.

Fishers appear to exhibit adaptive strategies in order to overcome economic and environmental constraints to income generation. Several researchers have identified the heterogeneity of fishers and their means of operating (Pet-Soede *et al.* 2001).

Strategies exhibited particularly in RAJ village were of specialisation rather than generalisation. These findings are in agreement with those of Smith & McKelvey (1986), who found that those with specialist fishing strategies had low flexibility, a limited number of other income generating activities and that the opportunity cost of an alternative livelihood option was high. In this case, it was less likely that specialised fishers, with large amounts of money invested in fishing gear would undertake cage based fattening of tilapia. Conversely, women at RAJ and men at USG were more generalist in their approach to fishing activities i.e. they could switch more easily from fishing activities to engage in unrelated activities (Salas & Gaertner, 2004). This is reflected in the lower numbers of fishing gears (with the exception of WML) owned by fishers in USG. In comparison to the specialist fishermen at RAJ, USG fishers and women at RAJ had more flexibility in their livelihood options as the opportunity cost of refraining from fishing was lower than that of a specialist.

Overall most households in RAJ earn greater incomes from fishing than those in USG. This is not related to the time that the householders spend fishing but is rather related to the amount of fishing gear used. From the data it was established that male-headed households in RAJ owned and used far more fishing gear than the householders in USG. They apportion a far greater importance to fishing as it is their only source of income due to lack of legal land ownership and lack of familiarity with agricultural practice. The importance placed on fishing is translated into the amount of resources they invest in it. Many nets are owned and money is spent or borrowed to purchase additional fishing gear on a regular basis. The fishers at RAJ have intensified their current strategy in order to survive negative trends such as decreasing individual catches and increasing fishing pressure. Just how sustainable this is in the long term remains the subject of some debate. In contrast farmers at USG have reached the maximum yields from their paddy land and have diversified into other activities such as fishing to mitigate negative trends in their principal income source. Intensification has not been an option for farmers and the shift to fishing has been the most lucrative locally available income generating activity available to them. Potentially intensification of and specialisation of fishing activities in USG may follow if pressure on land increases further and productivity of paddy cultivation declines further.

Households at RAJ are more vulnerable than the households at USG as they have a high co-variate risk (see (Ellis, 2000)). They are completely dependent on fishing. However, both villages depend on the tank water resource to support their livelihoods in either fishing or farming and auxiliary activities. Any change or shock to the tank water availability in either village would leave householders at considerable risk of famine as they depend on the tank for their food security. This is perhaps the motivation behind the government development of system tanks where water levels are controlled by water releases from upstream tanks, although the benefits of this control mechanism verses the rain-fed non-system tanks in terms positive or negative livelihoods impacts have yet to be demonstrated or modelled.

6.5.4 Contribution of the chapter

The findings of the quantitative livelihoods and fisheries survey compliment the qualitative information about the adoption and rejection of cage-based fattening of tilapia presented in Chapter 5. The data presented indicates the extent to which heterogeneity is present in a community, despite the apparently uniform context assumed in the initial phases. Previous work by Kodithuwakku (1997) highlighted the importance of entrepreneurial processes used by farmers to overcome livelihood failure in farming within a similar situation in Mahaweli System B where entrepreneurial farmers with the same original land allocations seized opportunities by mobilising misallocated agricultural resources and income diversification. This type of behaviour has been observed in USG and amongst the women in RAJ village, although much of this has been the result of 'push' factors rather than exclusively entrepreneurial processes at work.

To date the behaviour of fishers has received no attention within the literature on Sri Lankan fisheries. This research shows that fishing regulations are widely flouted and individuals employ strategies to mitigate seasonal reductions in fishing income and / or to exploit opportunities when catches of larger fish are high. The sample size, however, was small therefore further work in this area is needed to inform improved management strategies which currently fail to take the human behaviour element into account.

In addition to the behavioural element, little attention within the fisheries literature has been paid to selectivity of trammel nets with a limited number of studies found within the marine sector literature (Akiyama *et al.* 2004; Purbayanto *et al.* 2000; Fujimori, *et al.* 1996). The trammel net design enables the catch of fish by two different processes: gilling and entangling as known for conventional gillnets and catching of large fish taken in the bags of the inner netting. The existence of the latter catch process suggests that a larger amount of bigger fish should be taken. Consequently, trammel nets should be less size selective than conventional gillnets

(Hovgard & Lassen, 2000). The findings from the fisheries study are in agreement in this respect as medium and larger fish were more apparent in the trammel net catches. However, due to a lack of further test fishing in other areas of Sri Lanka, this work has no local contextual comparison to date. The policy implications of trammel nets' current banned status are discussed in the Chapter 7.

6.6 Conclusions

The combination of qualitative and quantitative techniques has established that there were several constraints to adoption of cage based fattening of tilapia and many factors in the limited adoption observed during the research period. The findings suggest that lack of adoption can be best interpreted by an amalgamation of technical, social and economic factors when taken as a whole. By investigating the nature of fishing, the main income generating activity in each community, the existing coping strategies for seasonal changes in fish catch have been identified in each community.

The following chapter discusses the broader implications of the findings, where they fit within existing knowledge and where relevant the potential for these findings to affect existing fisheries management approaches and policy in Sri Lanka.

Chapter 7 Discussion and implications of findings

The project investigated the potential to integrate aquaculture within existing irrigation structures in Sri Lanka in a context where aquaculture was not currently practiced. Previous attempts at promoting aquaculture in Sri Lanka were conducted by development institutions but have been dependent on external inputs and subsidies with a poor understanding of market demand and price structures. Identifying and testing opportunities for aquaculture to benefit the poor living around irrigation systems *in situ* was a key objective and has been met.

7.1 Summary of key findings

This study took a livelihoods approach to determine the potential for aquaculture within irrigation systems in North Western Province, Sri Lanka. A participatory situation appraisal conducted in several villages established that aquaculture was not technically feasible in the canal networks of the irrigation system due to high water velocities and intermittent supply characteristics. The research focus shifted to developing and piloting aquaculture in two of the system's numerous perennial storage tanks, which characterise Mahaweli System H irrigation and much of North Western Province.

A situation appraisal was conducted using participatory methods which identified areas of livelihood vulnerability for farmers and fishers. These included decreasing returns from agriculture and reportedly dwindling fish catches which appeared to have an important seasonal context. Landlessness or land shortages were identified as key constraints and the potential for pond aquaculture was disregarded at an early stage as being both technically and economically unviable (Wijerathne *et al*. 2001) and likely to exclude landless people. Consequently cage aquaculture in large irrigation reservoirs was developed a research focus to include the land poor. A review of the marketing situation through concurrent studies with F. Murray and focus group interviews in target villages concluded that if aquaculture was to succeed in this area it must compete in a market dominated by cheap and highly preferred tilapia derived from artisanal fisheries in perennial tanks. Limited availability of resources that could be used to fabricate cages and produce feeds made the challenge greater.

The situation appraisal also identified an apparent need for smoothing seasonal income from fishing. A potential role for cage-based fattening of tilapia was established as 1) a marketing appraisal indicated a demand for larger tilapia and 2) full cycle cage aquaculture of tilapia was not economically viable (Thayaparan *et al.* 1982). A high market demand for larger tilapia amongst vendors and consumers was identified. In contrast the apparent abundance of small, undersized tilapia in the catch during the situation appraisal led to the potential of fattening such fish being identified as a research focus. A participatory research process was initiated and after initial community meetings households in both USG and RAJ participated in a pilot scale trial. Locally available materials were identified and used to promote the sustainability of the activity by decreasing dependence on external inputs. Through this process of engagement with local communities cage materials such as bamboo, fishing nets, and galvanised metal meshes were identified as low-cost resources for cage construction. Initial testing of cage designs was conducted with participants in USG. This screening process revealed that greater consideration had to be given to the impact of predation on cage integrity and improved theft deterrent. Cage designs were modified using more expensive galvanised metal mesh materials, which although resilient to predation had larger mesh apertures (25.4 mm) leading to the negative effect of allowing entry of external fish to the cages during feed administration. This exacerbated poor performance of the fish during fattening.

7.1.1 Household vulnerability and the role of aquaculture

The work conducted with participants who initiated cage culture indicated that the culture system contributed little to household income. However, in USG village evidence from monitoring suggested that harvesting was stimulated by specific household needs rather than market demand. This suggested that to a small economic extent cage based fattening of tilapia did reduce household vulnerability through its use in meeting emergency requirements or other short term needs. This implies that even although the system was not important in its contribution to overall household income generation, fisher-farmers still stored or fattened fish and viewed it as a liquid asset in USG village. The fact that fish were easy to sell on a daily basis makes this a compatible means of saving for times of need or crisis.

One major constraint in this respect is the threat of poaching as cages are highly visible. Risk of poaching was found to be more likely to occur approaching the Singhalese New Year in the initial stages. This gives cause for concern as festivals place economic strain on households and any inclination to stock fish in cages in anticipation of festival expenses is likely to be met with a temptation to poach by other economically stressed individuals.

7.1.2 Aquaculture in a resource limiting context – key technical issues

The technical success of aquaculture was limited by the poor availability of high quality cage and feed ingredients in the local area. Improvisation using local materials to fabricate low cost cages and formulate on-farm feeds was necessary. However, as the cage design was influenced by the potential for cages to be fabricated using inexpensive materials and with low dependency on external inputs this process served to facilitate this purpose. Some implications of this situation are discussed below.

7.1.3 Cage, seed and feed availability

Durability in water of the local cage materials was only assessed *in situ* and *a priori* assessment of their useful working life in water was based on opinions of participants and retailers. This led to an inherent risk of overestimated durability of cage materials originating from the lack of experience in this regard and no available literature with the exception of Christensen (1995) (galvanised metal mesh) against which these materials could be realistically gauged. To this end the technical problems originated from both the durability of the cage materials but also the cage design itself. Bamboo cages were found to deteriorate within approximately 3 months and the net bag inside the cage was found to become increasingly fouled by the invasion of small minor cyprinids, attracted to the cage netting by feeding activities. Metal meshes with 25.4 mm^2 apertures permitted external fish to enter the cage during feed administration. Exclusion of these fish would likely lead to increased feeding efficiencies, reduced food conversion ratios and improve economic returns.

Seed, i.e. fish derived from the wild catch were limited in their availability as fishers from USG were more likely to land fish in the light of lower catches. Fishers in RAJ consistently caught larger fish in comparison to the catches experienced by fishers at USG, therefore they perhaps felt no pressing need for a system to supply them with yet more larger fish. They caught few small tilapia throughout the monitoring period and stocking cages in RAJ required special fishing by cast netting rather than, as envisaged, a by-product of gill or trammel net fishing.

Obtaining and processing feed ingredients presented a considerable constraint to preparing a high quality diet. Participants lacked equipment with which to sufficiently dry and grind minor cyprinids to prepare fishmeal. A consideration, however, is that the administration of a dried or powdered feed could be less effective in a small cage as it would flush out of the cage quicker than a moist feed ball.

As few alternatives existed participants used freshly ground fish to varying degrees but predominantly prepared low protein, high moisture, diets from household food waste and rice bran. In USG sieving the local rice bran was found to improve the quality on a weight for weight basis as husk was removed. Despite this many participants did not sieve rice bran on each occasion. Therefore the quality of feed presented was both variable in content but low in protein when expressed on a dry matter basis in comparison with the researcher – recommended feed. Feed quality has also been identified as a major issue in sustaining small-scale inland aquaculture in Vietnam (Hung, 2004), in Thailand (Supis *et al*. 2004), in Laos (Choulamany, 2004) and in Cambodia (Ngan *et al*. 2004). Development of more appropriate feeds will indeed take time and demonstrated benefits in terms of increased growth rates and high stocking densities is the only way in which this is likely to stimulate participants to undertake feed preparation on a larger and more time consuming scale.

Reece and Sumberg (2003) classify farming systems developed by farmers in terms of their tolerance and adaptability which equates to the amount of environmental or management variation the system can withstand before it is no longer fit for purpose. In this instance it seems that cage-based fattening of tilapia, which rapid fish growth is perhaps desirable, leaves little scope for variation as consistent feed administration and feed quality is needed to produce the best results for the marketplace.

7.1.4 Consumer preference

A consumer preference test in both USG and RAJ villages revealed that cage cultured fish were not preferred when compared with the tank caught fish. This has major implications for marketing fish reared in cage, although if cage fish are supplied to the market at times when the consumer has less choice due to decreased fish availability in tank, the cage fish may be accepted due to the lack of alternative choices.

7.2 Household level adoption of aquaculture

Some key social constraints in addition to the technical problems were also highlighted. Many participants in USG reported difficulties catching small tilapia with which to stock their cages. This was influenced in part by seasonality as the project commenced later than anticipated and coincided with a period of high water levels in the tank which resulted in decreased catches of small tilapia. Fish catches were reported to be lower than previous years. Fishers apportioned blame on unusually high water levels which persisted throughout the period of the farmer-managed cage trial, however, much of the catch in USG contained small tilapia for most periods of the year.

Other than the issues surrounding 'seed' supply participants became involved in other activities such as childcare or migration for employment to urban centres. Despite initial discontinuance in USG, a group of four cage operators continued in cage aquaculture and agreed to participate in a period of livelihood, fishing and cage operation monitoring against which a group of non-adopters and a cage operating discontinuing cage operator were compared.

In RAJ, many of the householders to whom cage materials were distributed did not stock or discontinued due to high mortalities experienced in the initial stages and concerns for cage security due to the distance between the homestead and the cage. Many households delayed their intention to undertake cage-based fattening of tilapia until water levels increased in the tank and their cage could easily be observed and accessed from their house. However, as the water levels began to increase cages were still not fabricated and installed. Further livelihood-based investigations of adopter, non-adopter and discontinuer households were conducted to determine which socio-economic characteristics might have influenced their decision to adopt or reject the technology.

Household - level livelihoods research demonstrated numerous constraints to adoption of cage-based fattening of tilapia in both communities irrespective of the participatory and inclusive methods in which cage-based fattening of tilapia was introduced and developed. These ranged from technical performance of the cage, socio-economic variables within households to access to resources. The study of adoption indicated that economic reasons for uptake of technology were less important and many variables normally associated with innovators and early adopters were also exhibited by non-adopters. The limitations of a small dataset constrained the development of key traits of adopters for two reasons 1) variability between adopters and non-adopters in the same village context and 2) variability in the assets of adopters and non-adopters between villages. Given a larger dataset and greater numbers of adopting households more generic traits of adopters in each village context may have been developed.

Less observable reasons for adoption or non-adoption of the technology merit consideration. These include variables related to communication behaviour and personality traits, which may have played a role in the decision-making process to adopt. However, these factors could not be investigated in full within the study period. Discussions with adopters revealed that they thought that the concept of holding fish and fattening to a marketable size at an appropriate time was useful. The perceived compatibility of, and need for, cage-based fattening as a complementary technology was also relevant. The perception of need, however, was possibly influenced by economic factors such as household income or perceptions of risk. Risk of poaching was an important factor for some women at RAJ. Gregory and Guttman (1996) indicate that whilst natural fish supplies remain adequate, there is little interest in fish culture. This perception may have been held by fishers in RAJ who did not adopt.

Further technical analysis of the system identified constraints experienced in practice which were not apparent during the situation appraisal and resource assessment. In USG the constraint to feed formulation was the inclusion of small minor cyprinids. Some households were inconsistent in their inclusion of fresh fish in their feed. This was due to a reluctance to fish specifically to make fish feed and the labour intensive nature of removing small minor cyprinids from nets. A cultural constraint emerged from "feeding fish to fish" which was not identified as a constraint in earlier community meetings. This contributed to lower inclusion levels in the feed and substitution with household food waste produced feeds with high moisture and low protein contents. In some households fish was omitted from the feed when stocking densities in the cage were low. As stocking densities were increased in the cage and the opportunity cost of feeding decreased then feed formulations included minor cyprinids. At RAJ feed preparation was hindered by competition for rice polish from a large-scale pig farming operation which made bulk collections periodically from the local mill. This was not anticipated by participants prior to the intervention and only experienced once cage-based fattening was underway. Female cage operators also struggled to obtain small tilapia with which to stock their cages. This was caused by lack of assistance by family members and friends on whom they relied on providing them with small fish and was compounded by their own lack of fishing gear with which small tilapia could be caught. Fishing data from RAJ also indicated that irrespective of gear types used the availability of small tilapia in the catch was very low which also constrained the viability of the intervention. Overall access to resources for stocking and adequate feed ingredients of consistent quality were constraints in both villages.

7.3 Alternative income generating activities

The presence of alternative income generating activities contributed greatly to the perceived need for cage aquaculture in each community. Although studies were conducted at the household level, no generalisations could be drawn between adopters and non-adopters to characterise them in this respect. A key complementary but also competitive activity in each community was fishing.

Fisheries

Examination of fish catches indicated considerable variability between fishers in each tank indicating a great degree of heterogeneity within either fishing community. Subsequent measurements of CPUE were disaggregated to reflect the gear types, number of gears used and time spent fishing. In this context this provided a more accurate account of CPUE compared to the traditional measure in kg/boat/day, which does not account for differing gear types and numbers of gears used between fishers. Acknowledging that trammel net fishing was illegal but in widespread usage, this fishery was examined through participants in the monitoring group with CPUE calculated in kg/hour. The data in both villages indicated that, despite being deemed less selective than gill nets, trammel nets consistently caught greater quantities of medium and large tilapia. In fact it was the gill net fishery in Usgala tank which exhibited proportionally larger percentages of small tilapia in the catch. In the longer-term it is more likely that the use of small gill nets is detrimental to fish stocks than trammel nets.

The situation appraisal in USG and RAJ indicated that in the gill net fishery,as water spread area increased CPUE decreased. This was validated by the study of the gill net fishery that concluded that CPUE had a highly significant negative correlation with water spread area in both villages. Fishers stated that in this particular year the water levels of the tank stayed higher than normal which was said to have affected fish catches. Fishing behaviour in the gill net fisheries of both tanks was found to change in response to increasing water spread conditions in a possible attempt by fishers to mitigate decreasing CPUE in relation to conditions. This indicated the dynamic and responsive nature of fishing as a livelihood activity. This also showed that the initial participatory situation appraisal was misleading. The results of the situation appraisal indicated that large fish were few and that small fish were numerous was questioned when the actual activities of fishers were monitored on a longitudinal basis. The fact that this occurred in both villages suggests that the validity of participatory situation appraisal as the sole means of identifying research or development foci is questionable. This finding however, may also indicate that the situations in fisheries with respect to conditions and catches are variable year on year and perhaps cannot be compared in such general terms.

Data collected from the trammel net fishery in USG found a highly significant positive relationship between overall CPUE and water spread area indicating that increased tank water levels were followed by higher catches. This indicates that trammel net fishing in USG is also sensitive to seasonal change in water spread area; however, this is the opposite situation to that of gill net fishing. This highlights a possible strategy used as fishers experience low catches with gill nets, shift gear and fishing method to more labour intensive trammel netting strategy.

A correlation between total CPUE and water spread area was not established for the trammel net fishery at RAJ which implied that catches in RAJ using the trammel net were more resilient to seasonal fluctuation than the gill net fishery.

7.4 Critique of the methodology

Due to the intensive nature of work within each community, more than two communities could not be selected due to logistic (principally staff availability) constraints. Working in a greater number of communities may have improved knowledge of the extent to which these results could be generalised within system H, but was not feasible during the project timescale.

The study showed that despite a situation appraisal phase at the beginning of the research project there were many socio-economic and resource constraints to aquaculture in practice in the villages in which the project intervened. Fisheries information gained at the situation appraisal appeared to be largely validated by the study. After the initial intervention phase in USG the fisheries shock banning smaller meshes had a considerable impact on the adoption rate of the technology as small fish availability decreased.

Monitoring of adopters, discontinuers and non-adopters would have benefited from larger group sizes to permit statistical comparisons. However, this was not the objective of the survey at the start and to some extent observing *who* participated in cage aquaculture became more important than how many people participated. Such comparisons may not have yielded further information as some socio-economic variables such as household income and education levels did not vary with adopter status. Group sizes were constrained by the number of people who had actually adopted aquaculture which meant this group size was 'self-selected'. Group sizes were also constrained by the number of household visits that enumerators could make within the monitoring interval. More intervals such as weekly visits would have provided greater clarity to the data given that fishing conditions can be highly variable. However, this was not possible due to a constraint on researcher's time. Some studies (Brugere, 2002) have delegated fishers to enumerate catches themselves, however, the validity of such data dependents heavily on trust; getting the right person. Watson (1999) reported that fishers have a tendency to over or underestimate their catches in anticipation of future benefits. To this end there were benefits to building rapport with communities to promote confidence in the information gained although enumerating oneself ensures consistency. This system also led to discussions about other activities in the village and contributed to building a deeper understanding of issues affecting livelihoods of the respondents interviewed.

7.5 Implications of the research findings

The experiences during the implementation of the farmer- managed research phase raise questions about how the validity of information collected in rapid participatory situation appraisals can be and its value in planning research interventions. It also highlights that village situations and livelihood activities are responsive and dynamic; hence situations that appear to have potential for aquaculture can change from one year to the next. Okali *et al.* (1994) argue that PRA do not generally, and perhaps cannot provide detailed information on what are often complex issues and processes. This view appears to have been borne out through these findings.

Furthermore the intervention sought to develop and test unproven aquaculture technology, which inherently carried an element of risk for participants. This highlights a pitfall of participatory research where developing technology with farmers may be fail to yield tangible results in the first trial cycle and project timescales may not permit multiple cycles of iteration. This has also been considered by Reece and Sumberg (2003) who state that releasing the technology at a very early stage may place considerable demands upon the ability and motivation of the potential end users to conduct further development work, thus running the risk of complete failure (Reece and Sumberg, 2003). Further development of the technology is needed in terms of improving cage performance, feed quality, food conversion ratio and growth and one may argue that had the system been more technically proficient, that adoption rates would have been greater.

The project did develop a process of participatory technology development of cage aquaculture which had not been attempted in Sri Lanka before. By engaging people in the process of technology development through their participation in the design, implementation and adaptation of cage-based fattening of tilapia, an insight into the relevance of the technology within the context of their daily lives was gained which could not have been observed if a more top-down, prescriptive approach had been taken. This provided some insights into the sustainability of cage-based fattening of tilapia such as the constraints of obtaining feed, preparing feed using own labour and resources, feed delivery, consumer acceptability and cage design issues. Further development toward alleviating the problems encountered in practice could address some of these issues and may contribute towards a more sustained uptake of the system.

In retrospect, this type of participatory technology development, particularly of a new activity with unproven technical efficacy was unlikely to deliver success within the timeframe of a typical research project. It is also possible that participant perceptions of the required complexity made cage-based fattening of tilapia unlikely to succeed. However, a new technology, complementary to livelihoods, was developed and potential impact assessed within the three-year field research period. Based on this experience 5-year project duration would be more realistic allowing further cycles of iteration and technical development.

7.6 Policy issues for consideration

The results highlighted a few areas for policy makers to consider in future planning phases.

7.6.1 Fisheries

The research results from analysis of fisheries in USG and RAJ showed that to a great extent, fisheries regulations are widely ignored by fishers in each community. Lack of enforcement and imminent threat of prosecution have led to continued contravention of fisheries regulations in each community. Increasing the number of extension officers and giving them greater power to prosecute illegal fishers would only further the top-down, leviathan approach to fisheries management. Much recent work has focused on community-based natural resource management and in particular co-management. Co-management is defined as the collaborative and participatory process of regulatory decision making among representatives of user groups, government agencies and research institutions (Jentoft, 1989; McCay & Jentoft, 1996). Almost all fisheries management goals have been explicitly based on a notion of collective societal good with which individuals are expected to conform, generally encouraged through some kind of coercion (Hart & Pitcher, 1998). As the results have shown, fishers in each community vary in both the types and number of gears and their income levels. It is perhaps simplistic to imply that the members of these communities have the same interests as the rest of their communities and is more realistic to assume their behaviour is based on their individual needs and capacities. Coercion by both the government or by a sense of community does not appear to be working in Sri Lanka as fishers consistently failed to comply with management regulations. Jentoft *et al*. (1998) argue that it is naïve to assume that co-management will transform established competitive and antagonistic relationships into co-operative ones and it is difficult to imagine how the situation will change under new management regimes, devolved or centralised, when communities cannot enforce rules against their own kind. The fact that both USG and RAJ tanks are large resources, each with multiple communities and many users, means that actions of the individual are less ‘observable’ and exclusion is difficult. Free-riding and illegal gear use, seem to be tolerated as other fishers’ empathise with the hardships of others. This was demonstrated in USG where the only complainants of the use of undersized gears at fishing society meetings were the wealthier individuals with other income sources who were less dependent on fishing as a livelihood activity.

While a lack of prosecution and culture of accepted illegal fishing practice exists, little is likely to change in inland fisheries management. Individual utility maximising behaviour seems to precede collective gain in each community. The results presented indicate that fishers change their fishing practices according to their needs. This has been demonstrated by the return to fishing for small fish after a period of hardship following a ban on night fishing and tightening of fishing regulations. It is also evident as fishers increase their fishing effort by increasing net numbers in response to decreasing CPUE and increasing water spread areas. This highlights the importance of understanding the role of household livelihood conditions as they have an influence on fishing behaviour and adherence to regulations.

Whatever the pitfalls, working more closely with fishing communities and attempting to devolve management decisions on a co-managed basis may be an improvement on the current ‘top-down’ system. Perceptions of what exactly constitutes participation (Chapter 1) will be important in this process.

Furthermore, the policy of banning meshes under 89 mm has not been established through scientific means and is based on the assumption that this mesh size will do no harm. To establish a legal minimum mesh size further work needs to be done to achieve this.

The results presented for both USG and RAJ fisheries demonstrate that trammel nets consistently caught larger fish in both tanks. Despite their reputation for being less size selective than gill nets their consistency in catching larger fish should be assessed in other tanks and is a potential avenue for further research. If this was validated in other tank fisheries the possibility of trammel nets to be considered a legal practice may be useful. Clearly it is better to catch fewer large fish than many small fish to sustain an income.

Reduced dependency on the fishery for income may assist stock conservation as the need to use all means possible to catch fish, i.e. using small meshes and catching small fish may become less attractive in the light of alternative income sources. The impact of any scenario where this has occurred has now been established. Reardon & Vosti (1995) introduced the concept of "investment poverty" when discussing the link between poverty and environment. Households which are "investment poor" are those who are unable to make minimum investment in resource improvements to maintain or enhance the quality and quality of the resource base, to forestall or reverse resource degradation. Households who are not necessarily "asset poor" may also be "investment poor". This seems to characterise some of the households studied in each community. For example, in USG all fisher households, irrespective of wealth category, chose to engage in illegal fishing methods. Despite a wish to catch larger fish poor catches forced fishers to catch smaller fish to supplement income. This is an example where households have been unable to invest in the resource due to pressure on existing income streams. The opposite is true in some households in RAJ when households with greater assets chose to invest not in the natural resource base but instead use their surpluses for consumption, savings or investments of other types i.e. in other asset categories other than natural capital.

The fact that the inland fishery is dominated by tilapia is its saving grace as fishing pressure at the extent to that recorded would be unsustainable if stocked fish were the dominant resource. This of course requires further research. However, it seems that tilapia populations are extremely resilient to the increasing fishing pressures, which in the prevailing socio-economic conditions of emerging future generations of fishers makes this the ideal fishery for resilience to the problems of developing countries. Current aquaculture development strategies promoted include rearing of *O. niloticus* and carp fingerlings in hapas, the former for release to tank fisheries and the latter for sale to pond owners. Steps to improve the capture fishery through re-stocking with *O. niloticus* fingerlings require large-scale assessment given the prevailing constraints implementing fisheries policy under present conditions. Hybridisation of tilapia readily occurs between *O. niloticus* and *O. mossambicus* (Amarasinghe & De Silva, 1996) which may hinder the objective of releasing *O. niloticus* to improve the existing tilapia stock.

7.6.2 Irrigation management and fisheries

The rights of fishers are not currently taken into account in irrigation planning initiatives. As demonstrated by the results, CPUE for gill nets fishers in both USG and RAJ tanks were related to water levels. In 'system' tanks water levels can vary swiftly according to upstream releases or irrigation issues. In Kalankuttiya and Kattiyawa tanks, Brugere (2002) indicated that CPUE was inversely related to tank capacity, although catches were substantially lower than those obtained at USG and RAJ tank. There is growing recognition of the importance of integrated water resource management for fisheries and fisher livelihoods (Murray, 2004; Dugan, 2005). Future irrigation and fisheries policy should consider the impact of changes in irrigation management on fish catches and plan according to the needs of both fishers and farmers.

7.6.3 Research policy

The more collaborative the research, the more likely it is to be driven by the needs and objectives of the participants. Therefore collaborative participatory research is not always compatible with the objectives of research teams who need to satisfy funding bodies to quantify impact or produce quantitative findings to justify expenditure (Martin & Sherington, 1997). There are issues with the expectations of funding bodies when this is the case, as they expect tangible research results from projects where in the field a more development-driven agenda is followed.

7.7 Contribution of the thesis

The research undertaken has shown that there are many limitations to the types of aquaculture which can be undertaken within irrigation systems with an explicit agenda of tackling poverty. The system of cage-based fattening requires further development if it is to become interesting to fishers in the future. At present, the perceived need for the system is small in the light of its low productivity in comparison to the tank fishery.

Introducing cage-based fattening of tilapia within the Sri Lankan context with limited resource availability and no tradition of aquaculture increased the challenge. However, the research has contributed to the knowledge of aquaculture research in Sri Lanka by adopting a livelihoods approach to aquaculture intervention and has also put people before production, unlike other top-down, externally driven research which has been implemented with generally poor success once external support is removed.

The thesis has also demonstrated that for differing reasons innovative and entrepreneurial behaviour is present as participants tested a new technology at their own individual social and economic risk. Gender issues have also been highlighted in particular their relevance to access to resources. Recognition that all female -headed households cannot be categorised in the same way has also been borne out in the research findings.

A key contribution of this research in the Sri Lankan context is the findings that trammel nets seemed to be responsible for catching larger fish and their ban should be reviewed. Fishing behaviour has also been found to vary with season, a factor which has never been explicitly examined or addressed with respect to its application in fisheries management policy making within the country. In addition to this, the work has demonstrated that fishers behave individually and this magnifies the difficulties of implementing current fisheries management policy in this context.

In conclusion, the concept of fattening tank caught tilapia using low cost feeds needs further development. In the right context where the system has a relative advantage over the existing capture fishery, potential for the system to contribute to livelihood security in a similar fashion to livestock holdings may hold some future potential.

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Appendix

Appendix 1 KAR Project R7123 Logical Framework

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal: Improved availability of water for sustainable food production and rural development	Productivity of water use in irrigation schemes increased through multiple - use management	Reports of target institutions	(Goal to Supergoal)
Purpose: Productivity of water use within irrigation systems enhanced through integrated aquaculture production	By 2005, in specified irrigation systems where production potential has been identified, aquaculture production increased by 50%	Reports of target institutions	(Purpose to goal)
Outputs: 1. Potential for integrated aquaculture within irrigation systems assessed and researchable constraints identified 2. Critical engineering and management constraints investigated and guidelines issues on how to integrate aquaculture within irrigation systems 3. Guidelines to research scientists and extensionists on ways to assist small-scale producers to develop aquaculture within irrigation systems 4. Policy guidance to planners and donors on when/where to promote integrated aquaculture within irrigation systems 5. Research co-ordination and output dissemination mechanisms implemented	1.1 By end of 1998: baseline review com pleted and reported to stakeholder meeting 1.2 By 1999: peer reviewed publication prepared for dissemination 2.1 By end 1998: stakeholders agree research agenda 2.2 By 2000: research in case-study sites leads to draft technical guidelines for integrating management of irrigation systems 3.1 By end 1998: stakeholders agree researchable issues 3.2 By 2001: trials completed at sites within each target country over two seasons and reported to dissemination workshop 4.1 By end 1998: irrigation institutions agree to participate 4.2 By 2001: in-depth stakeholder analysis leads to draft policy guidelines for each target country 5.1 By end 1998: detailed work plan agreed and reviewed periodically with ARP project R7064	Edited workshop output Peer reviewed publication Edited workshop output Project report Research action plan Edited workshop output Memorandum of understanding Project report Inception report Annual reports	(Output to purpose) Target institutions accept findings and promote integrated aquaculture

	5.2 By 2000: a well-attended regional dissemination workshop conducted 5.3 By 2001: dissemination plan agreed with DFID	Edited workshop report Interim report	
Activities: 1.1 Postal survey of aquaculture production within irrigation systems 1.2 In-depth study of current practice within target countries 2.1 Inventory of existing knowledge from published sources 2.2 Assessment of technical and socio-economic issues via stakeholder meetings 3.1 In-depth technical study of constraints to integrated aquaculture in selected irrigation systems 3.2 Develop in conjunction with NARS a farmer- ranked research agenda for development of aquaculture in irrigation systems 3.2 Participatory design of pilot scale action – research 3.3 Conduct action research at selected sites over two seasons including participatory evaluation 4.1 Consultations with policy-makers with interests in irrigation and water resources 4.2 In-depth socio-economic study of constraints to integrated aquaculture in the selected irrigation systems		Quarterly, annual and final reports plus financial statements	(Activity to output) Stakeholders are willing to participate and suitable case-study schemes are identified

Appendix 2 Participatory Situation Appraisal – Case Study Results

Table A1 Potential for poverty-focused aquaculture interventions in KAT Village, Kattiyawa Tank, Mahaweli System H, Sri Lanka.

	Potential for poverty focused aquaculture	Constraints to poverty focused aquaculture
Physical characteristics	• Medium size perennial tank • System tank with water level controlled by a feeder tank. • Some water inflow of drainage from surrounding areas. • Fishing activities in the tank regulated by the fishermen's co-operative society	• Potential for water quality problems arising from agricultural practices.
Shocks	• Awareness of fisheries management increased through the creation of the Fisherman's Co-operative Society. • Provision of credit through the fishing society at low interest rates for fishing related • Boats subsidised by government initiatives to increase fish catch from the inland reservoir fishery.	• Risk of future system-wide droughts reducing the level of water available in the Kattiyawa tank. • Variations in water level may prove problematic for fixed cage/pen culture.
Changes and trends	• Livelihoods diversified into fisher-farmer livelihoods rather than farming alone. • Reduced profit margins from farming due to increasing input costs and stable prices • Decreased agricultural workload due to the introduction of mechanisation. Labour may be available for aquaculture if less time is devoted to agricultural activities • Cessation of *chena* (slash and burn) farming and fewer employment opportunities for men. Aquaculture may provide a viable means of supplementary income generation • Farmers have diversified to incorporate fishing into their livelihood portfolio, indicating that a complementary activity such as fishing may be accepted as a further point of diversification • Decreased cattle availability in the village following the introduction of mechanisation. • Milk consumption decreasing due to decreasing availability of local fresh milk and the emergence of highly priced powdered milk in the local shops. Aquaculture may play a role in human nutrition by the consistent provision of affordable animal protein. • Increase in all food prices and reported reduction in the overall amount of food eaten because of high prices indicating potential demand for low cost	• Perceived increase in pesticide use affecting water quality. This may present constraints to aquaculture • Increasing dependence of Kattiyawa tank as a resource as other peripheral village tanks are being filled and converted to paddy by the Mahaweli Authority. Competitive water uses may have implications for the integration of aquaculture within the tank • Women not involved in fishing activities other than fish processing and drying. This could constrain their participation in aquaculture as a supplementary household activity •

	food such as fish. Also indicative that dependence on purchased goods contributes to vulnerability. Household aquaculture activity may reduce reliance on purchased foods and improve household food security. • Improvements in village transportation allowed improved access to markets that could also facilitate purchasing and selling of aquaculture products. • Emergence of the landless 2nd and 3rd generation with dependence on non-agriculture related work such as fishing and labour. Engagement in new income generating activities such as aquaculture may reduce household vulnerability by increasing their diversity of income sources.	
Seasonality	• Decreased fish availability in the rainy season, resulting in loss of revenues for fishers and an increase in fish price for consumers. Aquaculture may provide an alternative livelihood option for fishers and may stabilise seasonal price fluctuations. • Increase in price of most food commodities in the Maha monsoon season including fish while its availability is reduced. Aquaculture could potentially be targeted to meet the seasonal shortfall in supply • Fish consumption increased during periods of agricultural cultivation due to demands of workload and in-migration of relatives. Increased demand during these periods could be met by aquaculture.	• Seasonal availability of fish seed may be a constraint to full-cycle aquaculture • Increased workload and employment opportunities in agriculture particularly in the Maha season, coincide with the period of low fish availability therefore the optimal harvesting time for farmed fish. This may constraint aquaculture due to a decrease in available labour. • Roads degrade negatively affecting transport frequencies during the monsoon season. This coincides with the potential fish harvest period in Maha to meet the seasonal shortfall in fish caught from the tank fishery. Marketing of fish outside the village may be difficult at this time
Focus Groups	• Tilapia appears to be a favoured fish and can be cultured successfully • Decreased availability of local species that are preferred by consumers for their nutritious value and appearance. Farming of these species may fill a niche in the market. • Perceived decrease in the size of fish caught. Potential for the introduction of a fattening system for undersized fish. This will also meet the market demand for larger fish • Seasonality of fish catch has a negative impact on livelihoods. Aquaculture could be used as a seasonal activity and harvesting could be conducted in the off-season where there is less competition on price and availability from the tank fishery	• Local market demand for fish appears to be met. • Fishing families also trading fish in the village.

Table A2 Potential for poverty-focused aquaculture interventions in VIJ village, Kalawewa reservoir & head of RB canal, Mahaweli System H, Sri Lanka.

	Potential for poverty focused aquaculture	**Constraints to poverty focused aquaculture.**
Physical characteristics	• Large perennial reservoir located in close proximity to the village. • Right Bank Main and Yoda Ela canals located in close proximity to the village • Water velocity in canals is relatively high and supply characteristics intermittent and in response to farmer demand.	• Risk of water shortage in the Kalawewa tank. The tank failed to reach its full storage capacity in 1999. • Water velocity in the Right Bank Main Canal is high and supply intermittent and in provided in response to water availability and farmer demand. Irregular supply and high water velocity are undesirable for aquaculture interventions
Shocks	• A ban on *chena* (slash and burn) cultivation in 1975 resulted in the loss of one regular income generating activity. Aquaculture may provide an opportunity to supplement household earnings. • Purchase of boats by the government in 1982 to assist in exploitation of the reservoir fishery. Most boats are still in use today and could potentially be used for access to cage/pen aquaculture systems. • Shocks to agriculture such as the drop in chilli price in 1997 caused by trade policy allowing cheaper imports from India to flood the market, increase farming households' vulnerability. • Involvement in other income generating activities such as aquaculture may reduce household vulnerability to shocks	• The collapse of the Fishermen's Society in 1968 and again between 1985 and 1988 reflects the lack of co-operation between fishermen and the difficulties of managing the reservoir fishery. The lack of a cohesive fishing society may hinder the implementation of an aquaculture intervention. • A massive fish kill resulting in a fishing ban was also noted in 1988. Agro-chemical pollution was attributed to this. There is a risk of future pollution incidents adversely affecting aquaculture.
Changes and trends	• Decrease in the size of fish caught and catch volume. Aquaculture could potentially regenerate lost revenue to negate these trends. • Change in the composition of the catch with a reported marked decrease in the availability of indigenous species. This presents an opportunity for aquaculture to be used as a conservation tool and to fill a possible market niche. • Emergence of vendor preference for larger fish. There is potential for the fattening undersized fish to an acceptable market size. • Increased seasonal variation in the fish catch and fishing activities, adversely affecting livelihoods. Aquaculture may contribute to offsetting this trend if initiated in the summer months allowing harvesting to begin during the Maha low season. • Increased dependency on only one type of farming since the ban of *chena* cultivation. Integration of aquaculture into livelihoods portfolios may reduce vulnerability for fishers and farmers. • Reduced employment opportunities for younger people, especially the educated. Many are forced to return to the village and take up fishing and	• Decreased rainfall and reduced spill frequency of the reservoir. Increased water user use for irrigation may indicate future problems with water availability, undesirable for aquaculture. • Canal water pumped illegally, suggesting that the quantity of water available for aquaculture in the canal may be less predictable than the MA records. • Decrease of forest cover increasing the risk of run-off into the reservoir. This may affect water quality through increased turbidity.

	farming. Aquaculture may provide an alternative source of income for this group. • Decreased consumption of fish because of a rise in prices. Fish are more valuable to sell rather than consume. Household level production of fish may increase household consumption and have benefits for human health. • Increase in the price of all protein sources and vegetables, increasing vulnerability to human health where this is followed by a decrease in consumption. Household involvement in aquaculture could meet the household requirements for animal protein and improve human nutrition • Improved infrastructures and access to markets facilitating the sale of farmed fish.	
Seasonality	• Reduced protein consumption. • Meal frequency and quantity consumed reduced after April and in the summer until August. • Elevated fish price during the Maha season, sustained until April (New Year). • Seasonality of weather conditions make fishing difficult during the Warrakkan season when there is windy conditions. • Seasonality in income from fishing as catches decrease in the Maha monsoon season when water levels increase. Aquaculture harvests at this time could be used to offset the seasonal decrease in fish landings.	• Increased work opportunities in agricultural labour coinciding with the season of water availability in the canal and reservoir (September to February). This may reduce the availability of labour for aquaculture. • For farmers, household expenditures are increased during the cultivation period (rainy season), which is also the time of water availability and therefore may conflict with the feed requirements of aquaculture at the same time. This may not be true for fishermen whose working conditions and income earning are more difficult at this time of year.
Focus Groups	• Vendors do not accept small fish as demand for large fish is high. An opportunity for fattening smaller fish cost effectively remains an option. • Reduced availability of preferred indigenous species such as *Labeo dussumieri*. Culturing indigenous species may support a niche market if this can be achieved in a cost effective manner. • Fish consumption is high as its price is much lower than beef or chicken. Demand for fish is high. • Tilapia favoured by respondents and suitable for low-input cage aquaculture.	• High fish availability of tilapia in the village at relatively low cost. Aquaculture production has to compete with the high availability of wild fish on price and quality. • No fishing regulations and collaboration between fishermen, which may be a problem regarding theft, code of conduct etc. if aquaculture is implemented in the Kalawewa reservoir.

Table A3 Potential for poverty-focused aquaculture interventions in MDG village, middle of RB Canal, Mahaweli System H, Sri Lanka.

	Potential for poverty focused aquaculture	**Constraints to poverty focused aquaculture.**
Physical characteristics	• Presence of a small irrigation reservoir in the village (used to irrigate 40 acres of land) possible alternative to the canal for aquaculture (when the water level decreases too much, cages can be shifted to this water body). • Located on the Right Bank Main Canal which is the main water source for irrigation • Farmers are the principal beneficiaries of the irrigation system. However, the landless could potentially benefit from alternative uses of the irrigation system such as fish culture.	• Small village tank is a not a part of the system • Water velocity in the Right Bank Main Canal deemed too high for fish culture. • Water supply erratic in nature. • Potential for conflicts over water use in the village tank. • High number of encroaching weeds impairing access to the village tank. • Potential for high predation in both tank and canal.
Shocks	• The increasing pressure on water resources made droughts and conflicts over water allocation the main shocks. There is an obvious negative impact on livelihoods under these circumstances. Aquaculture could not be used as a means of reducing household vulnerability when water shortages are the cause.	• Occurrence of droughts not conducive to the objective of aquaculture as an activity to reduce vulnerability. • Conflicts over water allocation and management. The introduction of aquaculture as another water use may exacerbate existing conflicts if water availability and quality is perceived to deteriorate.
Changes and trends	• Increasing participation and consultation with farmers over water release schedules for cropping. Aquaculture, if attractive to farmers may be integrated within the water release schedules • Loss of indigenous fish species so potential for aquaculture to be used as a conservation tool. • Decreasing employment opportunities due to mechanisation, indicating that labour would be available for aquaculture, in particular from landless. • Dependence on dried fish as the main source of animal protein, suggesting a potential demand for fresh and affordable fish. • The increasing population pressure on local natural resources such as land and water supports the case for aquaculture as a non-consumptive use of water and an alternative or supplementary activity for resource poor (i.e. the increasing population of second and third generation landless). • Reduced cattle numbers indicates that livestock has been lost as an income generating activity. A supplementary income from aquaculture may mitigate the loss of income from cattle rearing.	• Reported increasing pollution due to pesticides could potentially affect cultured species. • Reduction in the forest cover, which may enhance run-off of agro-chemicals from paddy fields into water bodies. • Reported reduction in the quantity of water released for cultivation. A "non-consumptive" use such as aquaculture would potentially increase the competition and the productive capacity of water. • Emergence of migration trend for women abroad indicating that there are competing opportunity costs of their labour with implications for their involvement in aquaculture • All savings used for house maintenance. Potential for competitive use of savings if aquaculture introduced. • Inadequate marketing channels for fish may pose a problem for fish producers to dispose of their production and obtain full financial benefits.
Seasonality	• High water availability from September to February (Maha season). • Fish prices increase during the Maha season as availability decreases. This presents an opportunity for cultured fish to exploit the high price and low availability of tank fish at this time. • Festivities in April, May, June, during which demand for non-vegetarian food	• Unpredictable length of the dry season. • Heavy workload in Maha cultivation season (September to February) which may reduce the labour available for aquaculture at this time of year.

	increases. Producing large fish for these festivals would meet the market demand and potentially attract premium prices	
Focus Groups	• There is little current fishing practice within the village and as a result fish supply is dependent on outside vendors. Involvement in aquaculture could improve fish supply to the village and perhaps improve local demand for fresh fish	• Demand for fish in the village may not improve even if aquaculture is introduced

Table A4 Potential for poverty-focused aquaculture interventions in DOM, tail RB Canal, Mahaweli System H, Sri Lanka

	Potential for poverty focused aquaculture	Constraints to poverty focused aquaculture
Physical characteristics	• Village located in close proximity to the Right Bank Main Canal which would improve security and access to aquaculture interventions • Presence of 2 smaller irrigation tanks close to the village which may be considered for use as an alternative site for aquaculture intervention • Seemingly influential, cohesive and well organised Farmers' Association. Involving this group in aquaculture may provide good support to farmers and has the potential to offer credit.	• Potential for conflict over water use and access to the tanks with other resource users. • Access to the Right Bank Main Canal impaired by vegetation. • Water velocity in the canal deemed to high for fish culture. • Potential for high predation in both tanks and canals.
Shocks	• Government trade policies permitting cheaper imports from India for chilli and onion, affected farmers ability to sell their crops in the local market. There is a need for farmers to diversify into products which can be sold easily are not affected by international trade policy	• Unstable and unforeseeable weather conditions (droughts and floods) making participation in aquaculture more risky. • Farmers still repaying debts incurred from previous crop failures, therefore their capacity to invest in aquaculture may be limited. Current loan repayment commitments may financially constrain farmers' ability to participate in aquaculture.
Changes and trends	• Increased awareness of alternative income generating activities, particularly among women, who may be interested in participating in aquaculture. • Reduced employment opportunities and workload in agricultural labour especially among women, who may be available to participate in aquaculture. • Crop failures common during the Yala cultivation season. Another income generating activity such as aquaculture could mitigate these losses. • Increasing difficulty for farmers to sell their produce, highlighting the need for diversification. Aquaculture could be tested for its suitability in meeting farmers' needs. • Reduced availability of large fish indicating that there may be a potential to fill a niche in the market • Reduced consumption of all animal protein sources because of increased prices. There may be a potential niche for cheap fresh fish. • Increasing village population in particular, the landless that increases pressure on natural resources. A non-consumptive water use such as aquaculture may provide an additional income generating activity for the landless. • Deterioration of quality of life reported due to malnourishment and increasing food prices. Localised production of cheap fish could improve the nutritional status of consumers and reduce dependency on purchased food for producers.	• Decreasing water availability makes aquaculture unsuitable, as it is another water dependent activity that doesn't decrease household risk. • Decreasing forest cover and increasing agro-chemical use in the paddy fields may result in run-off contributing to water pollution. Poor water quality will have a negative impact on aquaculture.
Seasonality	• Higher food prices in the monsoon seasons in line with reduced supply during the cultivation season. Farmed fish could command high price if sold at this time of year.	• Unpredictable length and severity of dry season. • Unpredictable water availability

	• Limited employment opportunities for agricultural labourers towards November and December after all the agricultural work for land preparation has been completed for Maha cultivation season. • Increase in animal protein intake in April, i.e. at the end of Maha season / beginning of dry season.	• Seasonal water availability and quantity of water not always controllable as it depends on the rainfall and water level in the Kalawewa reservoir, presenting potential risks for completing aquaculture cycles.
Focus Groups	• Seasonal variation in the availability of fish with potential for aquaculture • General preference for tilapia which can be cultured easily • Reduced availability of indigenous species liked by respondents. Potential for aquaculture to fill a niche market for indigenous species.	• Current demand for fish appears to be met at present. • Locally available tilapia is relatively inexpensive. Culture of tilapia may not be economically feasible if current market price for tank tilapia is so low. • Seed supply for indigenous species may be problematic and culture may be economically unfeasible.

Table A5 Potential for poverty focused aquaculture intervention in USG village, Usgala Siyambalangamuwa Tank.

	Potential for poverty focused aquaculture research	**Constraints to poverty focused aquaculture research.**
Physical characteristics	• Medium size irrigation tank with perennial water availability desirable for long culture cycles if necessary. • Some livestock grazing on the side of the tank, potentially contributing to increased productivity of the water body	Risk of conflicts with other tank users.
Shocks	• Drought occurred in the 1970's. Farmers took a long time to recover from this shock. Integration of another income generating activity such as aquaculture may help mitigate the damage of negative shocks, decreasing household vulnerability. • Introduction of irrigation water in 1976 a positive shock to the village. • Construction of new fishing village to assist landless fishing families.	Risk of future droughts. As aquaculture would be affected by water availability, intervention of any water dependent livelihood activity would carry some risk.
Changes and Trends	• Reduced profitability of farming due to the intensification of agricultural practices through mechanisation and increased use of agrochemicals. An increasing landless population due to the emergence of the 2nd and 3rd generations has led to land fragmentation reducing the profitability of farming. Farmers have diversified into fisher-farmer livelihoods to try and increase household income. A complementary activity such as aquaculture may reduce vulnerability by providing additional income. • Increasing number of fishermen in the tank fishery due to lack of other income generating activities amongst the younger landlessness population. • Decreasing catch volumes for the individual and decreasing fish size have also been reported. Additional income generation through aquaculture may assist in offsetting this trend. • Reduced employment opportunities and subsequent increase in migration to other jobs for the young. Migration may be avoided if other income generating activities were available in the village. Aquaculture may be attractive if returns are comparable to other jobs. • Deforestation and jungle encroachment for agriculture and homestead construction, has led to increased crop damage contributing to farmers' vulnerability. A supplementary activity such as aquaculture may address this.	Fish consumption on the increase among fishing households.
Seasonality	• Seasonal competition between farmers as produce is marketed at the same time as other farmers due to water availability. No staggering of harvests means seasonal gluts of produce occur and the price falls. This contributes to farmer vulnerability as the value of their harvest is reduced. An additional income generating activity could be useful to provide a financial buffer to the household. • Employment in agricultural labour is seasonal, occurring at the start of paddy cultivation and at the harvesting period. High food prices in the Yala months coincide	Seasonal reduction of water spread area.

	with the lack of employment opportunities mid-cultivation cycle, increasing the vulnerability of landless labourers. Fish consumption in Yala increases as a substitute for vegetables due to their high price. Involvement in aquaculture may contribute to reducing household vulnerability though additional income generation and food security. • Seasonal fluctuation in individual catch volume and species of fish caught. Catches are reportedly high at the onset of the Maha monsoon in November when larger tilapia and carp are caught. The catch is lowest when the water level increases between January and February fish are more difficult to catch. As the tank water recedes between April and July, catches reportedly begin to increase. The seasonal variation in fish catch volumes, contributes to household vulnerability. Aquaculture could offset this by timing fish harvests when catches are low to supplement income and exploit a marketing opportunity.	
Focus group interviews	• Overall preference for tilapia and snakehead amongst respondents. Tilapia performs well as a cultured species and seed supply is not problematic. • Some illegal fishing practices exist. Involvement in aquaculture may have a positive impact on this by reducing fishers' need to catch fish illegally for income. • Undersized fish are landed but there is a general preference for larger fish by both fishermen and vendors as they seek a higher market price. There may be an opportunity for aquaculture to be used for fattening underside fish to an acceptable market size.	• Market flooded with cheap Tilapia for much of the year. • Economic viability of aquaculture is questionable as the market price of tilapia is low at Rs. 25/kg for small tilapia (approx 75-100g) and Rs. 40 for large tilapia (>250g).
Other observations	• Fishermen eager to resume the activities of the Fishermen's Co-operative Society. A cohesive fishing society may contribute to the successful implementation of any aquaculture intervention	• Tied relationships between fishers and vendors that may affect the capacity for fish farmers to negotiate a higher price for aquaculture fish.

Table A6 Case for poverty focused aquaculture in KAL village, Kalankuttiya tank

	Potential for poverty focused aquaculture research	Constraints to poverty focused aquaculture research
Physical characteristics	• Medium size irrigation tank with perennial water availability so fish can be cultured year-round • Seasonal variation in depth of tank at present allowing cattle grazing, which may contribute to increased productivity of tank water, desirable for aquaculture and culture-based fisheries of carp and tilapia. • Construction of a feeder canal to Kalankuttiya tank from Kattiyawa tank was underway at the time of survey. Water levels will be regulated by the release from upstream tanks, making water supply to this tank less dependent on catchment characteristics and therefore increasing the reliability of supply for aquaculture.	• Access to deeper areas of the tank in Maha may be impeded for those without access to a boat. Lack of access may exclude poorer people without access to a boat from participation in aquaculture.
Shocks	• Severe droughts in the 1970's and 1980's leading to economic losses to farmers and their households. Prevalence of droughts increases farmers' vulnerability and their need for other forms of income generation • This year the tank is closed to fishers due to the irrigation maintenance. This removed fishing as a livelihood activity, as fishing was banned. Some fishers who continue to exploit the fish stock at low water levels have ignored this ban. This may have a future impact on the fish populations in the tank. Regeneration of the fishery may take some time, therefore an additional income from an activity such as aquaculture could be beneficial.	• Risk of subsequent droughts affecting the availability of water for aquaculture. This may now be mitigated by the interconnection between Kalankuttiya and Kattiyawa tanks.
Changes and trends	• Increasing number of landless as the 2nd and 3rd generations emerge, causing an increasing number of young men to turn to fishing as a full time income source. • Increasing pressure on land due to the intensification of agriculture. • Reduced profitability of farming despite intensification. This is due to increasing costs of inputs, increasing land fragmentation and perceived reduction in soil fertility. There has also been a reduction in farm gate prices of agricultural produce due to cheaper imports from India and seasonal gluts of produce due to the inability to stagger harvesting periods. A supplementary income from aquaculture may be beneficial to help offset the financial impact these trends. • Reduced jungle areas due to encroachment for farmland and homesteads have led to increasing crop destruction by elephants. • Reduced employment opportunities particularly among young men as agricultural labour opportunities are seasonal and their availability reduced due	• Migration of young women excludes their involvement in aquaculture. • Improvement of infrastructure leading to increased ability to trade items such as fish. • Increased use of agrochemicals may have implications for water quality.

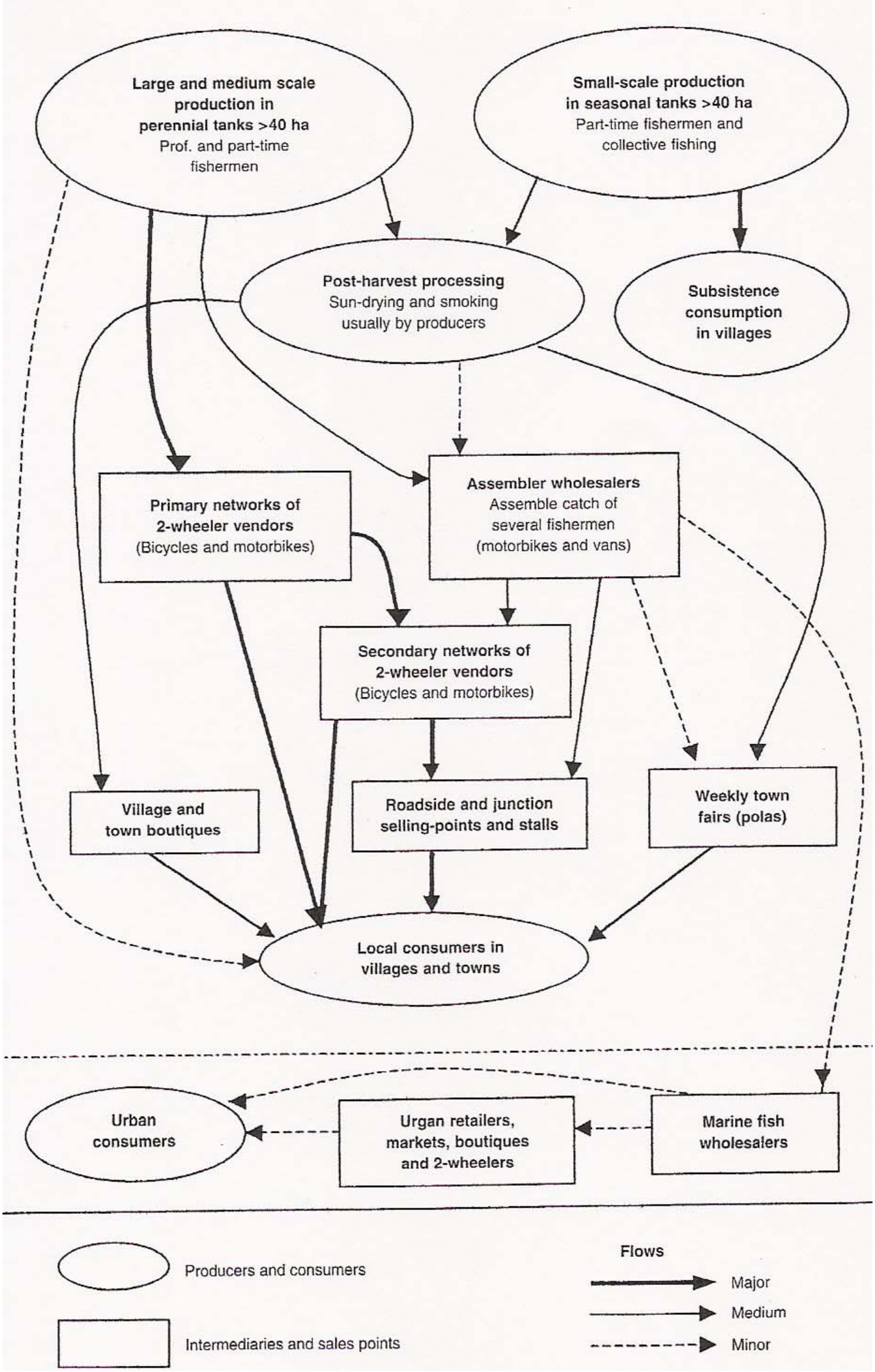
	to increased mechanised farming practices. Aquaculture could potentially provide supplementary income to reduce vulnerability • Increased migration of young women to jobs in urban centres and the Middle East. • Increasing reliance on remittances from children. • Reduction in the number of consumed items being met by the household production.	
Seasonality	• Seasonal variation in catch volume which varies with weather conditions, experience and gear used. • Fishing pressure increases during periods when there is little agricultural activity, contributing to the vulnerability of those reliant on fishing as their main income generating activity. • Seasonal unemployment during and between agricultural seasons, particularly affecting young men. • Increase in food prices during the Yala cultivation season. • Meal frequency reportedly reduced in the Maha cultivation season due to lack of cash and low food supplies. • Incidence of disease increased during the Maha months as these are likely to be related to the reduced meal frequency reported by male farmers.	• No change in price even when the catch volume is reputedly reduced. • Participation in aquaculture by seasonal entrants to fishing may result in a conflict between full time and part time fishers. Seasonal entrance has been tolerated by fishers so far.
Focus group interviews	• Strong links between vendors and fishers. • Overall preference for tilapia.	• Tilapia very cheap in system H.
Other observations	• Participation in aquaculture may increase the social status of fishers as this may be deemed as some form of farming.	• Fishing is perceived as a low caste activity which may not assist the acceptability of aquaculture in the community. Most wives did not want their husbands or sons to engage in fishing because of this social stigma. • Direct participation of women in water-based aquaculture is unlikely as they are not involved in fishing. This is not the social norm. Therefore, the direct involvement of women in aquaculture here is not feasible. There may be some scope to involve them in some other related activity which does not involve entering the tank, although feed preparation or post harvest processing are not likely to provide additional income generation for women if this is at the household level.

Table A7 Potential for poverty focused aquaculture intervention at RAJ village, Rajangana tank.

	Case for poverty focused aquaculture research	**Case against poverty focused aquaculture research.**
Physical characteristics	• Large irrigation tank • Perennial water availability (variable water level) • Village located on tank reservation land (settlement of encroachers)	• Risk of conflicts with other tank users • Risk of conflict with irrigation department
Shocks	• 1980 – drought conditions increasing household vulnerability and subsequent rises in the cost of food. • 1982 – Government started the fishing society and provided 90% funding for fishing boats. May of these boats still in service and can potentially be used for access to cages located in the tank. • 1990 and 1998 – Social unrest caused by local farmers as villagers from the fishing camp used land for small *chena* plots. Potentially involvement in aquaculture would reduce the need to find alternative income generating activities and would help their social inclusion. • 1992 – Road to the village constructed increasing the flow of goods to and from the village. This has been particularly beneficial to fish vendors and provides good marketing opportunities for aquaculture products. • 1998 and 2002 - Net seizures by authorities for illegal mesh size. Participation in aquaculture may offset the need for illegal fishing methods to augment income. • 2000 – Big storm during the monsoon season resulting in damage to boats and homes. No relief supplied by government. Involvement in another income generating activity would potentially help mitigate losses or assist with repayment of debt.	• Potential for other storms to cause damage to aquaculture ventures. • Further social unrest may jeopardise aquaculture if property is targeted. • Future for potential droughts may increase the risk associated with aquaculture as a supplementary income generating activity.
Changes and Trends	• Increasing livestock ownership indicating interest in diversification of incomes in some households. • Consumption of fish remains the same. Fish is consumed daily in most households, indicating that aquaculture may contribute to household food security • Shift from consumption of fresh milk to dried milk that is too expensive for many families, indicating that fish and eggs are important for household animal protein provision. • Increased fishing intensity in the tank threatening livelihoods. The number of boats in the village has changes from 15 to 40 over 10 years and the number of gears used per boat has increased. Mesh sizes are also decreasing in reputedly in response to low fish catches. Aquaculture of tilapia could provide and opportunity to offset this trend.	Cost effective production of large, preferred tilapia for the rural market may constraint its viability as a supplementary income generating activity.

Seasonality	• Seasonal change in availability of tilapia presenting an opportunity for aquaculture to supply the market when the production from the tank fishery is low. • Large and preferred tilapia only available in November and December, indicating that there is a marketing opportunity for aquaculture to produce larger fish for the market in the offseason for large fish as well as supplement household income when fish catches are low. • Seasonal variation in fish drying activity particularly affecting women and households unequipped to fish for tilapia. Participation in aquaculture	Seasonal variation in tank water level may affect water availability and water quality for aquaculture Receding tank water increases the distance to travel from the household to the tank.
Focus group interviews	Overall preference for Tilapia amongst fishers and consumers. Large tilapia preferred by fishers and vendors, although large tilapias are only available at the onset of the Maha monsoon in November. Good marketing networks at Rajangana tank and no tied relationships to vendors giving fishers greater influence over the price of fish at the point of sale. This is advantageous for marketing aquaculture products.	Market supplied with variable levels of relatively inexpensive tilapia for much of the year. Economic viability of full-cycle aquaculture is questionable.
Other observations	• Fishing is the sole income generating activity for nearly all households • Strong women's group interested in diversifying livelihoods • Female headed households amongst the poorest within the community • Women participate fishing with male relatives	

Appendix 3 Fish marketing distribution network and system actors (Source Murray, 2004)



Appendix 4 Cage materials identified during resource assessment

Sri Lankan resource assessment appendices

Table A8 Cage materials identified in Galgamuwa area

Material	Availability	Cost per unit		
Frame Casaurina wooden pole (5cm diameter approx.)	Not available			
Bamboo tubes	High	Rs 1 per ft	Rs 3.3/metre	According to Ft/stick
Split bamboo sticks	Not available in pre-fabricated form			
P.V.C. Pipe (20mm diameter)	High and local	Rs. 85/13ft length		
P.V.C. Pipe (32mm diameter)	High and local	Rs. 153.50/13ft length		
P.V.C. joints	High and local	Rs. 12 for 20mm t-joints Rs. 22.50 for 32mm t-joints		
Iron bar (1.0 cm diameter) - plain	High and local	Rs. 75/18ft		
Iron bar (1.0 cm diameter) - twist	High and local	Rs. 135/18ft		
Iron bar twist (1.2cm diameter)	High and local	Rs 105/18ft		
Iron bar (1.6cm diameter)	High and local	Rs. 210/18ft.		
Mesh Chicken wire 22 gauge (thick)	High and local	Rs. 54/m2		
Chicken wire mesh 26 gauge (thin)	Not available			
Floats Inner tubes of tyres	High and local	Ranging from Rs. 250-675		
Plastic water cans (20 litres)	High and local	100		
Plastic water cans (35 litres)	High and local	150		
Polystyrene blocks	High and local	65		
Anchorage Sandbags	High and local	Rs. 7-10		
Rice sacks	High and local	Rs. 5		
Large stone	0			
Moulded breeze block	Not available			
Miscellaneous Coir rope (1.5 cm diameter)	High and local	Rs 45/kg		
HDPE rope (1.5 cm diameter)	High and local	Rs 45/kg		
Padlocks	High and local	Rs. 165 - 265		

Table A9 Availability of wood from suppliers in Galgamuwa area

Type of Wood	Store Name	Length (ft)	Width (Inch)	Height(Inch)	Cost per foot (Rs.)	Estimated durability	Obtained from	Availability
Coconut	Junction Stores	6	3	2	13.50	> 1year	Kurunegala	High
	Junction Stores	7	3	2	13.50	> 1year	Kurunegala	High
	Junction Stores	8	3	2	13.50	> 1year	Kurunegala	High
	Junction Stores	9	3	2	13.50	> 1year	Kurunegala	High
	Junction Stores	10	3	2	15.50	> 1year	Kurunegala	High
	Razeek Stores	4	3	2	9.00	< 1year	Kurunegala	High
	Razeek Stores	5	3	2	9.00	< 1year	Kurunegala	High
	Razeek Stores	6	3	2	13.50	< 1year	Kurunegala	High
	Razeek Stores	7	3	2	13.50	< 1year	Kurunegala	High
	Razeek Stores	8	3	2	13.50	< 1year	Kurunegala	High
Sapu	Junction Stores	Any length	2	2	11.50	3-4 months	Kandy	High
	Deny Stores	<8	1	2	5.50	> 1year	Kandy	High
Ipil Ipil	Junction Stores	Any length	2	2	13.50	1.5 years	Local	High
	Junction Stores	Any length	3	4	45.00		Kandy	High
Pinus	Junction Stores	Any length	2	2	11.00	3-4months	Kandy	High
Kantha	Sapna Stores	5	2	2	12.00	6 months	Kandy	High
	Sapna Stores	6	2	2	12.00	6 months	Kandy	High
	Sapna Stores	7	2	2	12.00	6 months	Kandy	High
	Sapna Stores	8	2	2	12.00	6 months	Kandy	High
Durian	Deny Stores	<8	1	2	5.50	> 1year	Kandy	High

Table A10 Cost of fishing net meshes at Galgamuwa - Majeed Stores

Net material	Mesh size	Ply	Length (units)	Length (m)	Width (units)	Width (m)	Cost (Rs)
Nylon	9/10 inch	2	1500		400		2400
	2”	2	1500		40		375
	2”	3	1500		40		475
	2”	4	1500		125		600
	2”	6	1500		125		2000

Appendix 5 Pearson correlation analysis of relationship between total catch and no of fish stocked

Correlations - GNE

Correlations

		Total Catch (Kg/boat/day)	Total Stocked (monthly)
Total Catch (Kg/boat/day)	Pearson Correlation	1	.133
	Sig. (2-tailed)	.	.680
	N	12	12
Total Stocked (monthly)	Pearson Correlation	.133	1
	Sig. (2-tailed)	.680	.
	N	12	12

Correlations - WAN

Correlations

		Total Catch (Kg/boat/day)	Total Stocked (monthly)
Total Catch (Kg/boat/day)	Pearson Correlation	1	-.023
	Sig. (2-tailed)	.	.945
	N	12	12
Total Stocked (monthly)	Pearson Correlation	-.023	1
	Sig. (2-tailed)	.945	.
	N	12	12

Correlations - MBA

Correlations

		Total Catch (Kg/boat/day)	Total Stocked (monthly)
Total Catch (Kg/boat/day)	Pearson Correlation	1	-.018
	Sig. (2-tailed)	.	.957
	N	12	12
Total Stocked (monthly)	Pearson Correlation	-.018	1
	Sig. (2-tailed)	.957	.
	N	12	12

Correlations - NAN

Correlations

		Total Catch (Kg/boat/day)	Total Stocked (monthly)
Total Catch (Kg/boat/day)	Pearson Correlation	1	.120
	Sig. (2-tailed)	.	.710
	N	12	12
Total Stocked (monthly)	Pearson Correlation	.120	1
	Sig. (2-tailed)	.710	.
	N	12	12

Appendix 6 Pearson correlation analysis of relationship between relative contribution of small tilapia to income from fishing and no. of fish stocked

Correlations - GNE

Correlations

		Total Stocked (monthly)	Relative Contribution to Income from Fishing (%)
Total Stocked (monthly)	Pearson Correlation	1	.429
	Sig. (2-tailed)	.	.164
	N	12	12
Relative Contribution to Income from Fishing (%)	Pearson Correlation	.429	1
	Sig. (2-tailed)	.164	.
	N	12	12

Correlations - WAN

Correlations

		Total Stocked (monthly)	Relative Contribution to Income from Fishing (%)
Total Stocked (monthly)	Pearson Correlation	1	-.208
	Sig. (2-tailed)	.	.517
	N	12	12
Relative Contribution to Income from Fishing (%)	Pearson Correlation	-.208	1
	Sig. (2-tailed)	.517	.
	N	12	12

Correlations - MBA

Correlations

		Total Stocked (monthly)	Relative Contribution to Income from Fishing (%)
Total Stocked (monthly)	Pearson Correlation	1	-.055
	Sig. (2-tailed)	.	.864
	N	12	12
Relative Contribution to Income from Fishing (%)	Pearson Correlation	-.055	1
	Sig. (2-tailed)	.864	.
	N	12	12

Correlations - NAN

Correlations

		Total Stocked (monthly)	Relative Contribution to Income from Fishing (%)
Total Stocked (monthly)	Pearson Correlation	1	-.101
	Sig. (2-tailed)	.	.756
	N	12	12
Relative Contribution to Income from Fishing (%)	Pearson Correlation	-.101	1
	Sig. (2-tailed)	.756	.
	N	12	12

Appendix 7 Pearson correlation analysis of relationship between income from fishing and harvesting

Correlations - GNE

Correlations

		Kg. harvested / month	Mean daily income from fishing / given month
Kg. harvested / month	Pearson Correlation	1	-.173
	Sig. (2-tailed)	.	.611
	N	11	11
Mean daily income from fishing / given month	Pearson Correlation	-.173	1
	Sig. (2-tailed)	.611	.
	N	11	12

Correlations - WAN

Correlations

		Kg. harvested / month	Mean daily income from fishing / given month
Kg. harvested / month	Pearson Correlation	1	.327
	Sig. (2-tailed)	.	.300
	N	12	12
Mean daily income from fishing / given month	Pearson Correlation	.327	1
	Sig. (2-tailed)	.300	.
	N	12	12

Correlations - MBA

Correlations

		Kg. harvested / month	Mean daily income from fishing / given month
Kg. harvested / month	Pearson Correlation	1	-.271
	Sig. (2-tailed)	.	.395
	N	12	12
Mean daily income from fishing / given month	Pearson Correlation	-.271	1
	Sig. (2-tailed)	.395	.
	N	12	12

Correlations - NAN

Correlations

		Kg. harvested / month	Mean daily income from fishing / given month
Kg. harvested / month	Pearson Correlation	1	.101
	Sig. (2-tailed)	.	.755
	N	12	12
Mean daily income from fishing / given month	Pearson Correlation	.101	1
	Sig. (2-tailed)	.755	.
	N	12	12

Appendix 8 Household monitoring questionnaire and Cage Operator Questionnaire

Household Livelihood Monitoring

Date of visit		Family member interviewed	
Date of last visit		Relation to HH	
Respondent name		No of members in HH today	
Respondent number		No of absentees/guests (*please circle to indicate)*	
HH Code		Relation to HH	
Series number		Enumerator Name	
Non household members present		Yes = 1 No = 2	

Other income generating activities (other than fishing)

Unskilled labour

Have you or has anyone in your family done any labour in the past 7 days? (Yes = 1 No = 2)

Type of labour	Paid/unpaid	Who did the job	Where	No. of days worked last week	Rs./day	TOTAL	Did they submit to the wages to the household?

Other income

Have you or has a household member made any income from any other source in the past 7 days? (Yes =1 No = 2)

Item sold in the last 7 days	Amount sold (unit)	Unit price (Rs)	Total income (Rs)
Dry fish			
Dry salaya			
Eggs			
Buffalo milk			
Cow milk			
Other (specify)			
Cadjun			

Remittances (money coming in from family or others)

Have you or any other household member received money from anyone in the past 7 days? (y = 1/ n =1)

(This can be a working son or daughter paying "dig money" to family for living in the household)

Who sends it	Amount sent (Rs.)

(if any big payments came from the Middle East in past 2 weeks outside questionnaire time please ask)

Benefits, savings and credit.

Benefits

Have you received any benefit in the past 7 days? (Y=1 / N =1)

	Date of payment	How much received in past 7 days?	Who receives it
Samurdhi			

Savings.

Have you made any saved any money in the past 7 days? (Y = 1 / N = 1)

Type of institution	Who has the account	Rs. deposited
Samurdhi savings		

New credit taken

Have you taken any new credit in the past 7 days (Y =1 / N = 2)

Type obtained	Who has it?	What for?	Where from (bank/money lender, vendor)	Sum borrowed (Rs)	Instalment /month (Rs.) including interest	Interest rate (%)	Loan repayment period (months)	Payment made this month (yes/no)

Debt repayments

Have you repaid money towards any loans in the past 7 days (Y = 1 / N = 2)

Did you repay money towards any loans in the last 7 days?	Was payment due or paying off late or in advance	What was the loan for?	Total borrowed initially (Rs.)	Loan repayment period (months)	Monthly interest rate (%)	Total amount for each instalment	Total amount repaid this week (inc. interest)

Household consumption / purchasing.

Livestock.

Do you have any livestock (Y =1 / N = 2)

	Number owned	How much feed consumed per day?	What type of feed is it?	How much does it cost (Rs./kg)?	TOTAL COST PER DAY
Cattle					

Buffaloes					
Chickens					
Pigs					
Goats					

Number bought/sold (specify) - Price - TOTAL =

HH Consumption veg. items.

Items	Source	Price	No. of days consumed
Rice			
Vegetables			
Bread			

Home garden items used

Do you use any items from a home garden/ (Y=1/ N =2)

Item name *(tambili, carapincha etc.)*	Number used in the past 7 days

HH protein consumption

Protein source	Species	Where from?	Frequency of consumption (number days in the last 7 days)?	How much purchased (kg)/numbers?	What was the cost per unit (ie.Rs. per kg/per item)	How much is consumed at each meal?
Freshwater fish						
Marine fish						
Dried fish						
Other meats						
Eggs						
Milk						

Alcohol Consumption

Do you or any other household member spend money on alcohol? (Y =1/ N =2)

How much spent Rs. in the past 7 days? (Rs./day)	Frequency of Intake in the past 7 days.	Local kasipu or from shop.

Periodical expenditure (agricultural inputs, medicine, school books, uniform etc.)

Have you made any special purchases in the past 7 days? (Y = 1/ N =1)

Item purchased	Purpose	Where from?	Cost (Rs).

Institutional /social engagements (all meetings)

What meetings taking place in the village do you know about? List these and the person in attendance.

Date	Type	Who went?	Issues discussed	Conflicts?	Solutions reached?

If not in attendance but a member state reason for not attending___________________

Notes :

Appendix 9 Cage operator Monitoring Questionnaire

Participant name – **Date -**

Feeding sheet to be collected and renewed with participant.

Cage operation tasks.
Collect the details of who is doing what.

In the past 7 days who has prepared the feed (list all feed preparing persons below)	How many days has this person prepared feed?	How long does feed preparation take each person? (list a time per individual)	In the past 7 days, who has fed the fish in the cage? (list all feeders below)	How many days has this person fed the fish?	How much time per day does it take to feed the cage? (allocate a time to each person doing the feeding)

Incidental damages.
Have there been any poaching attempts or any damages to the cage? (Y=1 / N=2)

Incident	When did this occur ?(date)	Time spent repairing (hour)	No. of fish lost (approximate)	Approximated value of lost fish (Rs.)	Action taken
Cage damage					
Poaching					
Other (please specify)					

Stocking and mortality. ***(check these details against the participants record book)***

In the past 7 days, how many fish have you stocked?	Approximate size (cm)	Which method was used to catch them	Total number of fish in cage at the present time.	Number of mortalities observed in the past 7 days	Any special reason for stocking? (ie. excess catch/planning ahead)

Harvesting details and market price.

Number of kg. harvested	**No. of kg. sold to vendor**	Price per kg. which vendor gives	Size of fish sold to vendor (no.per/kg)	**No. of kg sold to neighbours**	Price per kg which neighbours pay (Rs.)	Size of fish (no. per kg.)	**No. of kg consumed at home**	Size of fish (no. per kg.)	**No. of kg. gifted to others**	Size of gifted fish (no.per kg)	Reason for harvesting this week

What are the proceeds of the cage harvest used for? *ie. loan repayment, day-to-day expenditure, expenditure for fishing nets or medicine etc.*

Requests for harvest.

Did vendor request you to harvest fish from the cage?

If so why did you choose to harvest or not to harvest from the cage when the vendor requested?

Have any neighbours or family requested you to harvest fish from the cage?

If so, why did you choose to harvest or not to harvest for the neighbours or family – why?

NOTES:

Appendix 10 Fish catch recording sheet

Interview Date ________________ **Fishing Site** ________________
Respondent name ________________ **How many days (No/seven days)** ____________
Enumerator name ________________

Fishing period Date(s) From _________ ***To*** _________

Fishing with partner (Y / N) *please circle*

Species	Code	kg caught TOTAL FOR **BOAT**	No. kg. Of fish to **each fishermen.**	No. of kg. **Sold** to vendor	**Price** of fish sold (Rs./kg)	kg retained for **drying**	kg **consumed in HH**
Teppili (small)	**1**						
Teppili (medium)	**2**						
Teppili (large)	**3**						
Loola	**4**						
Salaya	**5**						
Carps	**6**						
Others	**7**						

GEAR SHEET.
Gill nets

Mesh size (inches)	2		2.25		2.5		2.75		3		3.25		3.5		4		4.5		5		other	
Type of mesh Ny-**1**, Mono-**2**																						
No of meshes																						
Length of net (for each net used) specify units on sheet																						
Depth of net (for each net used) specify units on sheet																						

Cast nets
Cast netting______ Time spent cast netting _____ Mesh size_________

Trammel nets

	Mesh size 1	Mesh size 2	Mesh size 3	Length	Width	Nylon **1** / Mono **2**
Net 1						
Net 2						
Net 3						

Method of installing nets used _________________________

BEATING TIME - Trammel nets only

Time taken for **one beating session**	**No. of beating sessions** in this fishing period	**Total time nets** installed at **one site** (*approximate*)	How long does it take to **drop** nets at one site?	How long does it take to **lift** nets at one site?	Total active fishing time *(Calc. at entry stage)*	Total passive fishing time *(Calc. at entry stage)*

Time spent fishing – Gill nets only (beating /not beating)

	From	**To**
Time nets installed		
Time taken for beating		

Notes:

Appendix 11 Pearson's Partial Correlations of selected fishery-related variables in USG and RAJ villages

Partial Correlations - USG Gill nets

- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for.. RESPONDE

	AGE	EXPERIEN	NOGILLS	TOTALCAT	CPUE	TIME
AGE	1.0000	.7280	-.1532	-.2530	-.0053	.0240
	(0)	(95)	(95)	(95)	(95)	(95)
	P= .	P= .000	P= .134	P= .012	P= .959	P= .815
EXPERIEN	.7280	1.0000	-.2419	-.3505	-.0299	-.0484
	(95)	(0)	(95)	(95)	(95)	(95)
	P= .000	P= .	P= .017	P= .000	P= .772	P= .638
NOGILLS	-.1532	-.2419	1.0000	.3230	-.6244	.2537
	(95)	(95)	(0)	(95)	(95)	(95)
	P= .134	P= .017	P= .	P= .001	P= .000	P= .012
TOTALCAT	-.2530	-.3505	.3230	1.0000	.3607	-.0438
	(95)	(95)	(95)	(0)	(95)	(95)
	P= .012	P= .000	P= .001	P= .	P= .000	P= .670
CPUE	-.0053	-.0299	-.6244	.3607	1.0000	-.3730
	(95)	(95)	(95)	(95)	(0)	(95)
	P= .959	P= .772	P= .000	P= .000	P= .	P= .000
TIME	.0240	-.0484	.2537	-.0438	-.3730	1.0000
	(95)	(95)	(95)	(95)	(95)	(0)
	P= .815	P= .638	P= .012	P= .670	P= .000	P= .
WATER	-.1023	-.0857	.3982	.0396	-.4561	.4053

	(95)	(95)	(95)	(95)	(95)	(95)
	P= .319	P= .404	P= .000	P= .700	P= .000	P= .000
CPUESMAL	.1168	.2043	-.3368	.0665	.5480	-.0147
	(95)	(95)	(95)	(95)	(95)	(95)
	P= .254	P= .045	P= .001	P= .518	P= .000	P= .886
CPUEMED	-.0434	-.1452	-.1977	.1092	.2812	-.2135
	(95)	(95)	(95)	(95)	(95)	(95)
	P= .673	P= .156	P= .052	P= .287	P= .005	P= .036
CPUELAR	-.1074	-.1595	-.3246	.3366	.5364	-.3340
	(95)	(95)	(95)	(95)	(95)	(95)
	P= .295	P= .119	P= .001	P= .001	P= .000	P= .001

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

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- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for..   RESPONDE

	WATER	CPUESMAL	CPUEMED	CPUELAR
AGE	-.1023	.1168	-.0434	-.1074
	(95)	(95)	(95)	(95)
	P= .319	P= .254	P= .673	P= .295
EXPERIEN	-.0857	.2043	-.1452	-.1595
	(95)	(95)	(95)	(95)
	P= .404	P= .045	P= .156	P= .119

NOGILLS	.3982	-.3368	-.1977	-.3246
	(95)	(95)	(95)	(95)
	P= .000	P= .001	P= .052	P= .001
TOTALCAT	.0396	.0665	.1092	.3366
	(95)	(95)	(95)	(95)
	P= .700	P= .518	P= .287	P= .001
CPUE	-.4561	.5480	.2812	.5364
	(95)	(95)	(95)	(95)
	P= .000	P= .000	P= .005	P= .000
TIME	.4053	-.0147	-.2135	-.3340
	(95)	(95)	(95)	(95)
	P= .000	P= .886	P= .036	P= .001
WATER	1.0000	-.0697	-.3477	-.2744
	(0)	(95)	(95)	(95)
	P= .	P= .498	P= .000	P= .007
CPUESMAL	-.0697	1.0000	-.2874	-.1558
	(95)	(0)	(95)	(95)
	P= .498	P= .	P= .004	P= .127
CPUEMED	-.3477	-.2874	1.0000	-.0866
	(95)	(95)	(0)	(95)
	P= .000	P= .004	P= .	P= .399
CPUELAR	-.2744	-.1558	-.0866	1.0000
	(95)	(95)	(95)	(0)
	P= .007	P= .127	P= .399	P= .

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

Partial Correlations - USG Trammel Nets

- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for.. RESPONDE

	AGE	EXPERIEN	TOTALCAT	CPUE	TIME	CPUESMAL
AGE	1.0000	.7646	.0758	.0144	.1144	-.2301
	(0)	(88)	(88)	(88)	(88)	(88)
	P= .	P= .000	P= .477	P= .893	P= .283	P= .029
EXPERIEN	.7646	1.0000	.2073	.2006	-.0019	.0039
	(88)	(0)	(88)	(88)	(88)	(88)
	P= .000	P= .	P= .050	P= .058	P= .986	P= .971
TOTALCAT	.0758	.2073	1.0000	.4331	.2329	.0792
	(88)	(88)	(0)	(88)	(88)	(88)
	P= .477	P= .050	P= .	P= .000	P= .027	P= .458
CPUE	.0144	.2006	.4331	1.0000	-.6331	.1297
	(88)	(88)	(88)	(0)	(88)	(88)
	P= .893	P= .058	P= .000	P= .	P= .000	P= .223
TIME	.1144	-.0019	.2329	-.6331	1.0000	-.1411
	(88)	(88)	(88)	(88)	(0)	(88)
	P= .283	P= .986	P= .027	P= .000	P= .	P= .185
CPUESMAL	-.2301	.0039	.0792	.1297	-.1411	1.0000
	(88)	(88)	(88)	(88)	(88)	(0)
	P= .029	P= .971	P= .458	P= .223	P= .185	P= .
CPUEMED	.0426	.1004	.4091	.5724	-.2803	-.2964
	(88)	(88)	(88)	(88)	(88)	(88)
	P= .690	P= .346	P= .000	P= .000	P= .007	P= .005
CPUELARG	.0884	.0922	-.0905	.3051	-.2672	-.0237

	(88)	(88)	(88)	(88)	(88)	(88)
	P= .407	P= .387	P= .396	P= .003	P= .011	P= .825
WATER	.0316	.1873	-.0669	.3434	-.5591	.0498
	(88)	(88)	(88)	(88)	(88)	(88)
	P= .767	P= .077	P= .531	P= .001	P= .000	P= .641

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for..   RESPONDE

	CPUEMED	CPUELARG	WATER
AGE	.0426	.0884	.0316
	(88)	(88)	(88)
	P= .690	P= .407	P= .767
EXPERIEN	.1004	.0922	.1873
	(88)	(88)	(88)
	P= .346	P= .387	P= .077
TOTALCAT	.4091	-.0905	-.0669
	(88)	(88)	(88)
	P= .000	P= .396	P= .531
CPUE	.5724	.3051	.3434
	(88)	(88)	(88)
	P= .000	P= .003	P= .001

TIME	-.2803	-.2672	-.5591
	(88)	(88)	(88)
	P= .007	P= .011	P= .000
CPUESMAL	-.2964	-.0237	.0498
	(88)	(88)	(88)
	P= .005	P= .825	P= .641
CPUEMED	1.0000	-.4950	.3633
	(0)	(88)	(88)
	P= .	P= .000	P= .000
CPUELARG	-.4950	1.0000	-.1153
	(88)	(0)	(88)
	P= .000	P= .	P= .279
WATER	.3633	-.1153	1.0000
	(88)	(88)	(0)
	P= .000	P= .279	P= .

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

Partial Correlations – RAJ Gill nets

- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for.. RESPONDE

	AGE	EXPERIEN	TOTALCAT	NETS	TIMEPASS	WATER
AGE	1.0000	.3594	-.2443	.0114	.3530	.0639
	(0)	(138)	(138)	(138)	(138)	(138)
	P= .	P= .000	P= .004	P= .894	P= .000	P= .453
EXPERIEN	.3594	1.0000	.2013	.2314	-.2253	-.0315
	(138)	(0)	(138)	(138)	(138)	(138)
	P= .000	P= .	P= .017	P= .006	P= .007	P= .712
TOTALCAT	-.2443	.2013	1.0000	.3453	-.2724	-.1387
	(138)	(138)	(0)	(138)	(138)	(138)
	P= .004	P= .017	P= .	P= .000	P= .001	P= .102
NETS	.0114	.2314	.3453	1.0000	-.0234	.2392
	(138)	(138)	(138)	(0)	(138)	(138)
	P= .894	P= .006	P= .000	P= .	P= .784	P= .004
TIMEPASS	.3530	-.2253	-.2724	-.0234	1.0000	-.2288
	(138)	(138)	(138)	(138)	(0)	(138)
	P= .000	P= .007	P= .001	P= .784	P= .	P= .007
WATER	.0639	-.0315	-.1387	.2392	-.2288	1.0000
	(138)	(138)	(138)	(138)	(138)	(0)
	P= .453	P= .712	P= .102	P= .004	P= .007	P= .
TOTCPUE	-.2161	-.0352	.3489	-.3008	-.2277	-.0202
	(138)	(138)	(138)	(138)	(138)	(138)
	P= .010	P= .679	P= .000	P= .000	P= .007	P= .813
SMACPUE	.0226	-.0020	.1784	-.0437	-.0659	-.1292
	(138)	(138)	(138)	(138)	(138)	(138)

	P= .791	P= .981	P= .035	P= .608	P= .439	P= .128
MEDCPUE	-.2115	.1195	.5430	.0303	-.2531	-.1386
	(138)	(138)	(138)	(138)	(138)	(138)
	P= .012	P= .160	P= .000	P= .722	P= .003	P= .102
LARCPUE	-.1444	-.0762	.1357	-.3040	-.1302	.0446
	(138)	(138)	(138)	(138)	(138)	(138)
	P= .089	P= .371	P= .110	P= .000	P= .125	P= .601

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

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- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for..   RESPONDE

	TOTCPUE	SMACPUE	MEDCPUE	LARCPUE
AGE	-.2161	.0226	-.2115	-.1444
	(138)	(138)	(138)	(138)
	P= .010	P= .791	P= .012	P= .089
EXPERIEN	-.0352	-.0020	.1195	-.0762
	(138)	(138)	(138)	(138)
	P= .679	P= .981	P= .160	P= .371
TOTALCAT	.3489	.1784	.5430	.1357
	(138)	(138)	(138)	(138)
	P= .000	P= .035	P= .000	P= .110
NETS	-.3008	-.0437	.0303	-.3040
	(138)	(138)	(138)	(138)
	P= .000	P= .608	P= .722	P= .000

TIMEPASS	-.2277	-.0659	-.2531	-.1302
	(138)	(138)	(138)	(138)
	P= .007	P= .439	P= .003	P= .125
WATER	-.0202	-.1292	-.1386	.0446
	(138)	(138)	(138)	(138)
	P= .813	P= .128	P= .102	P= .601
TOTCPUE	1.0000	.0504	.1506	.9355
	(0)	(138)	(138)	(138)
	P= .	P= .554	P= .076	P= .000
SMACPUE	.0504	1.0000	-.0964	-.0448
	(138)	(0)	(138)	(138)
	P= .554	P= .	P= .257	P= .599
MEDCPUE	.1506	-.0964	1.0000	-.1847
	(138)	(138)	(0)	(138)
	P= .076	P= .257	P= .	P= .029
LARCPUE	.9355	-.0448	-.1847	1.0000
	(138)	(138)	(138)	(0)
	P= .000	P= .599	P= .029	P= .

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

Partial Correlations RAJ Trammel Nets

\- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for.. RESPONDE

	AGE	EXPERIEN	TOTALCAT	TIME	CPUE	WATER
AGE	1.0000	.6665	-.2655	-.1774	-.2647	.1017
	(0)	(74)	(74)	(74)	(74)	(74)
	P= .	P= .000	P= .020	P= .125	P= .021	P= .382
EXPERIEN	.6665	1.0000	.1122	-.0028	.0175	.0670
	(74)	(0)	(74)	(74)	(74)	(74)
	P= .000	P= .	P= .334	P= .981	P= .881	P= .565
TOTALCAT	-.2655	.1122	1.0000	.4619	.8850	-.2542
	(74)	(74)	(0)	(74)	(74)	(74)
	P= .020	P= .334	P= .	P= .000	P= .000	P= .027
TIME	-.1774	-.0028	.4619	1.0000	.0869	-.0705
	(74)	(74)	(74)	(0)	(74)	(74)
	P= .125	P= .981	P= .000	P= .	P= .455	P= .545
CPUE	-.2647	.0175	.8850	.0869	1.0000	-.2950
	(74)	(74)	(74)	(74)	(0)	(74)
	P= .021	P= .881	P= .000	P= .455	P= .	P= .010
WATER	.1017	.0670	-.2542	-.0705	-.2950	1.0000
	(74)	(74)	(74)	(74)	(74)	(0)
	P= .382	P= .565	P= .027	P= .545	P= .010	P= .
SMALCPUE	.0953	.0377	.0531	.0865	-.0046	-.4242
	(74)	(74)	(74)	(74)	(74)	(74)
	P= .413	P= .746	P= .649	P= .458	P= .969	P= .000
MEDCPUE	-.0915	.2441	.6424	.3286	.4487	-.2275

	(74)	(74)	(74)	(74)	(74)	(74)
	P= .432	P= .034	P= .000	P= .004	P= .000	P= .048
LARCPUE	-.1741	-.2139	.2305	-.2322	.5242	-.0212
	(74)	(74)	(74)	(74)	(74)	(74)
	P= .133	P= .064	P= .045	P= .044	P= .000	P= .856

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed

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- - - P A R T I A L   C O R R E L A T I O N   C O E F F I C I E N T S - - -

Controlling for.. RESPONDE

	SMALCPUE	MEDCPUE	LARCPUE
AGE	.0953	-.0915	-.1741
	(74)	(74)	(74)
	P= .413	P= .432	P= .133
EXPERIEN	.0377	.2441	-.2139
	(74)	(74)	(74)
	P= .746	P= .034	P= .064
TOTALCAT	.0531	.6424	.2305
	(74)	(74)	(74)
	P= .649	P= .000	P= .045
TIME	.0865	.3286	-.2322
	(74)	(74)	(74)
	P= .458	P= .004	P= .044

CPUE	-.0046	.4487	.5242
	(74)	(74)	(74)
	P= .969	P= .000	P= .000
WATER	-.4242	-.2275	-.0212
	(74)	(74)	(74)
	P= .000	P= .048	P= .856
SMALCPUE	1.0000	.1381	-.2386
	(0)	(74)	(74)
	P= .	P= .234	P= .038
MEDCPUE	.1381	1.0000	-.5200
	(74)	(0)	(74)
	P= .234	P= .	P= .000
LARCPUE	-.2386	-.5200	1.0000
	(74)	(74)	(0)
	P= .038	P= .000	P= .

(Coefficient / (D.F.) / 2-tailed Significance)

" . " is printed if a coefficient cannot be computed