Potential for Aquaculture in Community-Managed Irrigation Systems of the Dry-Zone, Sri Lanka: Impacts on Livelihoods of the Poor.

By

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DECLARATION

This thesis has composed in its entirety by the candidate and no part of this work has been submitted for any other degree.

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Abstract

Rainfed areas in the Dry-Zone of Sri Lanka are characteristic of extensive marginal agro-ecosystems known as the semi-arid tropics (SAT) populated by poor farming communities. In the Dry-Zone and elsewhere, the traditional response to seasonal water scarcity was to construct rainfall-harvesting devices known as 'tanks'; created by building earthen dykes across ephemeral streams in undulating terrain. Most are held in common ownership by adjacent communities, who use them for multiple functions including irrigation, bathing and fishing. Storage efficiency is enhanced by arranging tanks in cascading sequence within watersheds so that drainage waters can be re-used. The aim of this study was to evolve improved collective strategies for the management of seasonal water bodies (focussing on aquatic production) in order to reduce the vulnerability of the poorest groups.

Understanding of these complex systems requires a holistic approach which integrates hydrological, biological and socio-economic factors on a suitable (watershed) scale. Work commenced with a comprehensive situation analysis, culminating with the formulation of a participatory research agenda for action research based on low-input stocking enhancements.

Village livelihoods have traditionally revolved around paddy cultivation as the primary tank function; however, in recent times, water-use strategies have responded to a range of demographic, economic and environmental pressures with implications for the sustainable management of natural resources, especially living aquatic organisms. Natural fish production in the most seasonal tanks relies on intermittent spill-events which link successive tanks; these provide migration routes which permit recruitment of stocks from lower perennial tanks. Rehabilitation initiatives that increase the storage / irrigation capacity of tanks or poorly designed surplus weirs that impede migration have negative impacts on fisheries, though they are rarely considered by planners.

The fundamental concept of the purana complex (PC) as the smallest logical sub-component of the watershed for intervention is introduced. Within PC boundaries discrete community groups bound by ties of kinship and caste, control access to private and commonly held natural resources. PCs in the uppermost reaches of

watersheds are distinguishable by the highly seasonal nature of their tanks and poor physical infrastructure relative to lower watershed communities. Such areas are also often buffer zones between as yet uninhabited hinterlands and settled areas where cultivation potentials are further restricted due to wild animal incursions. Consequently, these groups exhibit the greatest dependence on exploitation of the natural resource base. This often includes less seasonal tanks in lower PCs where fisheries are of less significance to local livelihoods. Such low-level 'poaching' is generally well tolerated, but potential for conflict exists where development efforts restrict hitherto free access to these resources.

These findings were the basis for two phases of action research which involved the stocking of ten tanks belonging to seven communities in North West Province (2000-2001). Phase 1 trials encompassed a range of social and physical and settings from lower to upper watershed. Results indicated that the use of costly hatchery-produced seed was unlikely to be sustainable given (1) a background of highly erratic natural production (2) uncertain returns to individual effort and (3) a low priority accorded to fish production from village tanks given the availability of low-cost commercial production from perennial reservoirs.

The second phase was restricted to low-caste communities in upper watershed areas and relied entirely on wild-fish stocks captured from perennial reservoirs lower in the watershed. Also emphasis was on intermittent 'staggered' harvesting using hook and line gears rather than the single intensive 'collective harvests' adopted in phase 1 trials. High yield potentials were demonstrated in the smallest tanks (<4ha) which were devoid of fish stocks during two pervious drought years. Results also indicate that sustainable adoption will be likely only where there is strong social cohesion and representative village leadership. An adaptive learning process which can demonstrate the net benefits of staggered harvesting in seasonal tanks is described.

These stocking strategies combined with tank rehabilitation sympathetic to preservation of upstream hydrological linkages, are highly complementary enhancement steps. Results clearly show that together they have potential to maintain the wider aquatic ecosystem on which the poorest groups depend.

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Glossary of terms and abbreviations

Abbreviation	Term
Anicut	A river dam and diversion for the purpose of irrigation
Bethma	Flexible freehold system of paddy cultivation in drought years
CDR	'Complex, diverse and risk prone' environment
Chena	Traditional slash and burn cultivation in upland areas.
CF	Cropping frequency, collective fishing or condition factor
CPR	Common property resource
CPUE	Catch per unit effort; a measure of fishing efficiency
Bethma	Flexible freehold of irrigated paddy lands during drought years
DAS	Department of Agrarian Services
DDS	Death Donation Society; and indigenous village welfare society
DFID	Department for International Development
DS	Divisional Secretariat; lower administrative tier
GoSL	Government of Sri Lanka
Goyigama	Dominant farming / land owning caste within Sinhalese society
GN	*Grama Niladhari*: village level administrative officer
GN Division	*Grama Niladhari* Division; lowest village level administrative tier
Karaka	Traditional wicker hand trap designed to catch snakehead fish
*Maha**	Main cultivation period associated with monsoon bringing maximal rainfall (October to March)
MBCA	Mutually beneficial collective action
MWS	Maximum tank water-spread area obtained at full supply level (FSL)
NGO	Non governmental organisation
NWP	North West Province
OAR	Open access resource
Petav pola	A shoal of juvenile snakehead, protected by their mother
Pinpadi	'Poor dole' small supplementary allowance targeted at the very poor
PIM	Participatory impact monitoring
PRA	Participatory rural appraisal
Poya	Buddhist holiday coinciding with each full moon
Pradeshiya Sabha	Town council
Purana village	Traditional 'old' village
PC	*Purana* Complex: Socio-physical entity comprising a communities bound by kinship and caste, their tanks and other common resources
RRA	Rapid Rural Appraisal
Rs	Sri Lankan Rupees; Sterling exchange rate =Rs68-131, Jan98- Jan02
Salvenia	Nuisance introduced floating aquatic macrophyte
Samurdhi	Main welfare benefit received by over half the population
Samurdhi Niyamake	Government welfare extension officer / animator
SAT	Semi-arid tropics
Seettu	Village small group rotational savings and credit system
Shramadana	Public service activity traditionally associated with religious merit
STC	Small Tank Cascade
*Yala**	Secondary cultivation period associated with monsoon bringing lesser rainfall (April to September)
Variga	Sinhalese endogamous kinship group
Vel vidane	Traditional hereditary village irrigation headman

* Note: The timing of these seasons is reversed to the north and south of the hill country massif.

Chapter 1 Introduction

1.1 Introduction: scope and objectives

This study has two main aims; firstly, to identify social, technical and economic constraints to the integration of aquaculture in small-scale community-managed irrigation reservoirs, subject to seasonal water availability. Secondly, to develop effective approaches to aquaculture, which benefit the poor. A third aim relates to the development of improved methodologies for undertaking this kind of multi-disciplinary research. Research outputs include guidelines to engineers, extension workers and policy makers.

The work was conducted alongside a Department for International Development (DFID) project which aimed more generally, to assess the potential for aquaculture in small-scale engineered water systems managed by farmers, located in water stressed areas (where there is high seasonal and inter-annual variation in water availability with regular periods of acute water shortage). A large proportion of the world's poor live in these mainly rainfed areas with undulating terrain and problem soils where they face a future of water and food scarcity. The marginal type of agriculture characteristic of these areas into which aquaculture has to be integrated has been described as complex diverse and risk prone (CDR – Chambers, Pacey *et al* 1989).

Although Sri Lanka is classed as having a tropical-humid climate, this reflects average conditions skewed by high rainfall levels in upland areas. Some two thirds of the land-area constitutes a lowland Dry-Zone where low rainfall coupled with high potential-evapotranspiration rates, averaging 2,100 mm/year, result in negative annual water balances, i.e. where potential evapotranspiration exceeds annual precipitation (Gamage 1997). Consequently, farmers experience water deficits for much of the year and short growing periods (from <90 to 150 days) under rainfed conditions are the norm. This setting is characteristic of extensive subtropical belts stretching around the world known as the semi-arid tropics (SAT). The primary research sites for this study were located in the North West Province (NWP) of the Dry-Zone.

Despite extensive development of large scale irrigation systems during the 20th Century, the majority of farmers in the world, including the poorest farmers in CDR regions continue to place great reliance on small-scale rainfed irrigation to increase the low productivity associated with dry-land cultivation (Wolf 1986). In Sri Lanka, as in extensive areas of southern India, watershed management mainly exists in the form of ancient community-managed village reservoirs or ‘tanks’ arranged in cascading sequence to conserve water. Large-scale rehabilitation of this resource has taken place over recent decades in both countries.

It has been predicted that India and Sri Lanka will face a fresh-water crisis in the near future (Nigam *et al* 1998), and as much water is currently wasted due to inadequate management and conservation practices there is a need for more integrated approaches to water management (Redding 1990). Aquaculture for example can used to increase the productivity of scarce water when undertaken in conjunction with other uses. However, attempts to promote fish production in such areas have been rare and typically based on conventional commercial semi-intensive pond aquaculture. Whilst the resource-rich have been able to adopt such an approach, it has proved inappropriate for poorer marginalised people.

The integration of aquaculture into village tanks is also complicated by their common pool and multiple-use characteristics. In addition to their primary irrigation function, tanks are used for bathing and domestic purposes, livestock production, fishing, and a range of micro-industrial functions. As storage and regulation devices, they also provide a range of ‘common goods’ including soil and water conservation, ground water recharge for perennial cropping, flood control and they play an important role in the ecology of the surrounding area. Finally, they fulfil ritual and symbolic roles which mediate social relations of prestige and power. A correspondingly wide range of interest groups associated with these different functions means that tank management is unavoidably political.

Previous attempts to promote fish production in village tanks, which tended to emphasise only bio-physical constraints, have failed in part due to a poor understanding of this complexity. By any objective measure, such failure is extensive; large-scale stocking programmes using hatchery-cultured carps are well documented from the early 1980’s onwards. Yet the extent of this failure is rarely acknowledged by policy makers or development organisations. As a result substantial development assistance continues to flow into contemporary projects (ADB 2002) with little evidence of any substantive change in their *modus operandi* towards tank stocking. A key task in this research was to gain better understanding of the complex and interacting factors underpinning previous failures. Although not a focus of this thesis, I hope such understanding might help to improve the targeting of future aid.

The adoption of a participatory approach within a highly inter-disciplinary research mode resulted in an unorthodox thesis structure. Work commenced with a detailed situation analysis followed by two phases of action research, based on low-input fisheries enhancements. However, rather than commencing work with pre-formulated hypotheses, action research hypotheses were designed only after extensive consultation with primary and secondary stake-holders and evaluation of the preliminary situation analysis. These hypotheses are presented in Chapter 5, prior to the outcomes of corresponding phases of action research. Earlier chapters deal with the biophysical and social contexts of the research areas and these findings are used to interpret and extend the generalisability of action research outcomes. Because of the interdisciplinary structure, methodological detail in is generally given at the start of each chapter; only Chapter 3 (methods for social data gathering) is dedicated entirely to methodological description. A brief summary of the content of each chapter is given at the end of this chapter.

This chapter continues with a discussion of the theoretical frameworks underpinning the research after which ways of classifying irrigation systems in terms of their potential for poverty-focused aquaculture are explored. Next I summarise current thinking regarding the commons and their potential for collective / community management, and characterise small-scale village tanks as common property resources (CPRs). I go on to assess the demand for inland fish and examine the history of stocking enhancements in Sri Lanka. Next, I give a description of the research areas based on results of a wide-ranging preliminary situation analysis. Finally I present the research framework and details of the screening process for selection of research sites.

1.1.1 Theoretical frameworks

A farming systems approach provided the overarching framework for the work. This indicates what is required in general terms for a technology to be sustainable for poor farming households. The narrow technical aspects of aquaculture are considered in conjunction with social, economic and environmental aspects in order to increase the likelihood of sustainable adoption (Edwards 1999).

The systems approach also stresses the need to consider the hierarchy of systems that influence rural aquaculture if its potential is to be realised at household level (Edwards and Demaine 1997). These range from individual animals or plants, to farming subsystems (including aquaculture), which contribute to individual household livelihoods, to systems operating at larger macro-levels at community, regional, national, and international levels (Conway and Barbier1990). Major issues at the macro-level included marketing, institutional issues and government policy, (Murray 2004a). In order to understand the farming and social systems supported by village tanks, work resolved from watershed, to village and ultimately to household and intra-household level.

A second overlapping framework used to assess the potential for aquaculture to alleviate poverty is that of the sustainable livelihoods framework (Carney 1998, Scoones 1998). Livelihoods comprise capabilities, assets (financial, human, natural, physical and social) and activities required for a means of living by individuals or households. They are sustainable when they can withstand stresses and shocks and maintain or enhance capabilities and assets, both now and in the future, whilst not undermining the natural resource base. The framework incorporates a 'vulnerability context', which includes cultural practices, long term trends and short term shocks that the poor may be particularly affected by. Capital assets are affected by transforming structures (e.g. institutions, government) and processes (e.g. laws / incentives). These determine who gains access to which type of asset, its effective value and thus, which strategies and activities are attractive to whom; generating livelihood outcomes. Feedback loops connect 'transforming structures and processes to the vulnerability context and livelihood outcomes to capital assets. Although referring to the poor the framework builds on positives such as assets rather than starting from an analysis of their needs.

Financial, physical and human capitals obey the orthodox economic definition of capital whereby a rate of return to investment can be calculated. The natural resource base has only recently been viewed in this sense although valuation is problematical given multiple benefit streams and vague definitions of ‘economic life’ (Ellis 2000). Social capital, also a relatively recent concept (Coleman 1990, Putnam *et al.* 1993) is perhaps this framework’s greatest operational limitation (Ellis *ibid*, Stirrat 2004). It is viewed as covering personal networks, as opposed to more formal community institutions such as farmers associations etc. (Ellis *ibid*). While such networks are of great significance in a developing country context, the practical application of the concept in describing political, social or economic change still requires considerable clarification. Ellis (*ibid*) also suggests that the framework should be far more explicit about the impact of social institutions and relations, e.g. gender, kin, class, caste, ethnicity and belief systems, in shaping livelihood outcomes through their influence on resource access. These constraints were especially problematical for this research with its focus on common pool resources. The livelihoods framework also makes no explicit reference to the scale factors, which are central to the systems approach.

Research work commenced with a conventional project planning approach whereby a log-frame (Appendix 6) was developed based on secondary data and a literature search. This provisioned for the development of a more detailed research agenda based on stake-holder and needs analysis. However, these meetings revealed a marked divergence between perceptions of primary and secondary stakeholders (Chapter 5). Furthermore, an extensive grey literature did little to clarify the highly complex situation that was being observed on the ground with respect to community-managed tanks. Consequently, the log-frame progressively gave way to a more flexible and iterative rolling planning approach with emphasis on primary stakeholder participation.

This was consistent with both farming systems and livelihood approaches, which suggest that technology evaluation should be undertaken by beneficiaries rather than through the demonstration of preconceived ideas (Scoones 1998, Edwards 2000). The key to this approach rests on the careful choice of indicators, which should reflect project objectives but in the context of broader livelihood systems, i.e. not confined to the aquaculture sub-system alone. The participatory impact monitoring (PIM) techniques (Estrella 2000) employed over the course of this study sought to reveal why the changes brought about by different interventions were more or less successful with different interests groups; in terms of the number of cases of uptake and the quality or nature of the uptake. Iterative adjustments to the technology were made according to this information.

1.2 Reservoir classification and aquaculture potential

In this section, I will attempt to produce a broad classification of reservoir systems; tanks in particular, with focus on their potential for poverty-focused aquaculture. Reservoirs can be classified according to tenurial, structural or functional perspectives, with the adopted system reflecting the priorities of the user. This diversity also reflects the multi-purpose nature of most reservoirs.

In both India and Sri Lanka, irrigation systems are categorised for administrative purposes into major and minor systems. In Sri Lanka, the classification is based on the size of the irrigable area command areas (CoA - Table 1.1). Major and medium systems are the responsibility of the Irrigation Department, while the Department of Agrarian Services (DAS) is responsible for minor systems.

The constraints and opportunities for the poor to benefit from integrated production of aquatic organisms in large, institutionally-managed systems are likely to be very different to the potential for farmers to manage various forms of micro-irrigation. I will therefore use an administrative categorisation of irrigation as being under the control of (1) the household or immediate community (small-scale) or (2) an outside institution, typically an irrigation authority or department (large-scale). Communities around smaller systems are likely to have greater ability to manage their own water resources with less intervention from external institutions. This contrasts with the situation for major and medium systems where the Irrigation Department is responsible for maintenance and operation with limited participation of farmer organisations.

In terms of aquatic production potential, it is also useful to classify reservoirs in terms of hydrological criteria, notably supply characteristics and their reliability for cultivation (Palinasami *et al.* 1997, Murray *et al*. 2002, Gowing 1998). Large-scale 'system' reservoirs' receive assured water supplies through their strategic location on perennial rivers, or via feeder canals linking them to other reservoirs, lakes, streams and rivers, often in adjacent basins. In this research, we are interested in a sub-set of smaller community-managed reservoirs known as 'tanks'. These are mainly non-system or 'rainfed' reservoirs, i.e. they receive runoff only from rainfall on their own catchments. Non-system tanks can be divided into two further groups (1) 'chain or cascade tanks' receive surplus / drainage waters from upper tanks and / or feed lower ones; most of the minor irrigation systems in the Dry-Zone conform to this definition (2) much less common are 'isolated tanks', which neither receive nor supply water to other tanks.

Table 1.1 Administrative classification, access and aquatic production characteristics of irrigation systems in India and Sri Lanka (after Murray *et al.* 2002, Haylor 1994)

Administrative classification	Major (2)	Medium (1 or 2)	Minor (1)	Micro (1)
Water source	Large dams and canals constructed on perennial rivers	Reservoirs fed by run-off (or cross basin diversions	Reservoirs fed by ephemeral surface or ground water	Rain and silt harvesting devices or ground wells
Seasonality	Perennial	Perennial or seasonal	Mostly seasonal	Perennial only with ground supply
Water-spread	> 200ha	50-200ha	1-50ha	< 0.1-1ha
Command area	> 600ha	80-60ha	< 80ha	< 1ha
Water allocation and operation	State	State or community	Community	Community or individual farmers
Construction	Outside contractors	State	State or Community using local materials	Community or individual farmers
Maintenance	State	State	State and / or local community	Community or individual farmers
Limnology	Natural productivity and CPUE* for stocked species is low	Higher natural productivity to vast draw-down area	Increasing natural productivity. Highest CPUE for stocked species	Manageable by farmer interventions

1 = Small-scale: household or community-managed
2 = Large-scale: formally managed by an institution outside the local community
* Catch per Unit Effort

Tanks which receive assured water supplies via trans-basin diversion are likely to be larger perennial systems. Rainfed tanks are much more numerous; they are prone to highly seasonal variation in water storage even to the extent of completely drying. Consequently, they are also referred to as ‘seasonal’ tanks. Their seasonality characteristics will determine the potential for fish survival during dry seasons and in cascading systems, intermittent hydrologic linkages determine the potential for fish migration and natural repopulation.

Govind and Sukumaran (1989) classify tanks in Tamilnadu according to water retention characteristics as follows: seasonal 3-4 months, long seasonal 8-10 months, or perennial. However this simple classification ignores historic variability and more critically, user perceptions, and hence definitions of seasonality are likely to differ significantly with respect to functionality; especially for cultivation and aquaculture (Chapter 2).

Ellis (1963) distinguishes tanks by their catchment characteristics: (1) net or micro-catchment is the area which drains directly into a lower tank (2) gross or meso-catchment is the combined catchment area above any tank. Gross catchment therefore includes the net catchment of any superior tanks from which runoff reaches the lower (axial) tank as surplus (spill) or drainage returns. ‘Radial’ tanks receive runoff only from their own micro-catchment. In Chapter 2, this spatial distinction is combined with a definition of seasonality based on drying frequency, to produce a typology of natural aquatic production potential.

A further categorisation relates to the primary use of tanks as either for (1) irrigation or (2) ground water recharge. Whilst both share a similar design, the latter lack sluice structures and are more likely to be constructed on high permeability soils. In Tamilnadu, India, many ‘abandoned’ irrigation tanks have effectively been transformed into percolation tanks as a result of a surge in tube-well construction for lift irrigation.

Irrigation systems also comprise the following functional subsections: water collection, water delivery, on-farm application and waste water removal. In larger systems, there is potential to incorporate aquatic production in each of these components. Under smaller seasonal village tanks in water-stressed areas, potential is realistically confined to the storage subsection, i.e. the reservoir itself. Although small-scale water storage has been practiced for thousands of years, attempts to integrate fish production into these systems are few, concentrated mainly over recent decades (Haylor 1994) and restricted to conventional capture fisheries approaches.

1.2.1 Community-managed tanks

Tanks are man-made water harvesting structures that store the rainfall runoff from monsoon rains for supplementary or assured crop irrigation during the dry season in addition to a range of ancillary uses. They are created by constructing earthen embankments (bunds) across seasonal streams in undulating terrain (Chapter 2). They are less common in more level terrain, where longer bund works are required to contain shallower depths. Tanks are deepest close to the bund where they can retain water for as little as 3-4 months or as much as 12 months per year, the storage period varying from year to year. In addition to their physical configuration and hydrology, they are also highly distinct in terms of their social roles and management systems (Chapter 4).

Irrigation will tend to become progressively more supplementary under smaller, more seasonal tanks, i.e. farmers here will rely more on direct rainfall combined with irrigation releases which are less frequent than those under larger perennial tanks. Consequently, they also face a higher risk of crop losses and can expect lower average yields compared those achieved under perennial systems.

The term ‘tank’ is often used inter-changeably for larger and smaller reservoirs built according to this principle, though originally the name appeared to be reserved for smaller-scale village structures reflected in it’s derivation from the Portuguese *tanque* meaning pond. In this study I restrict use of the word to describe simple earthen impoundments small enough to be managed by local communities with no reliance on external institutions for their routine operation.

1.2.2 Regional distribution of cascading tank systems

Tanks have also been a traditional response to seasonal water availability in both south and south-east Asia; most notably in northern Thailand, India and Sri Lanka. But nowhere are they as well developed as in the hard rock areas of Peninsular India, the Chotanagpur plateau in eastern India and the Dry-Zone of Sri Lanka (Agarwal and Narain 1998). In India there are estimated to be more than 253,000 minor tanks with command areas ranging from less than 10ha up to 500ha (Dhan 2001). The Deccan plateau of peninsular India covering substantial areas of Andhra Pradesh, Karnataka, Tamilnadu and Kerala States, has over 140,000 of this number. These tanks which cover over 273,000ha when full, supply more than one third of the total irrigated area in the same states (Palinasami *et al.* 1997). A further 26,000 tanks are concentrated in Orissa (Govind and Sukumaran 1989, Shanmughan and Vasimalai 1998). Cascading tank systems are most developed in Tamilnadu and Sri Lanka where there are estimated to be over 39,000 and 18,000 minor tanks respectively (Palinasami *et al.* 1997, Jayaraman 1997, Sakthivadivel, Fernando *et al* 1996). In Sri Lanka these are arranged into between 3,500 to 4,000 small tank cascade systems (STC – Chapter 2). Compared to other Indian states, there are relatively few large major reservoirs in either or Tamilnadu and Sri Lanka, though intermediate sized reservoirs (<5,000ha) are relatively abundant.

The spatial distribution and general form of individual tanks is determined by various climatological, social and physical factors. Topographic and geologic / soil characteristics are responsible for a broad divergence in tank development in the Indo-Gangetic and Peninsular regions. In the sloping rocky terrain of South India and Sri Lanka, tanks are situated at short distance one below the other forming the hydrologically interlinked chain or 'cascade' described above, i.e. with a high drainage density. Arranging tanks in cascading sequence also brings greater relative benefits in drought prone areas (Table 1.2). By contrast, tanks of the flat, alluvial northern Indo-Gangetic plains and much of Eastern in India tend to be isolated, fewer in number. They benefit from more stable hydrological characteristics; they are typically deeper with more uniform depth, both depth and area fluctuations are less erratic, water tables are higher and water retention generally superior.

In flatter areas of Tamilnadu (<1% gradient) with heavy alluvial soils, ratios of bund length to tank circumference can rise to more than 40% (Dhan 2001). In steeper sloping areas where lateritic red soils with high run-off rates predominate, the ratio rarely exceeds 10-25% (giving tanks here their characteristic half moon shape). Although the former tanks may have inferior supply characteristics, this is compensated for in part by the high water retention levels of black soils and correspondingly lower crop irrigation requirements. However the lower drainage density, rainfall and greater investment required to maintain tanks in such terrain means that villages here access smaller numbers of tanks compared to villages in sloping areas.

Table 1.2 The relative merits of cascading systems (after Palinasami *et al.* 1997)

Criteria	Cascading tanks	Isolated tanks	Comments
1. Evaporative losses	Higher	Lower	Higher in smaller shallower (radial) tanks characteristic of upper cascade areas
2. Conveyance losses	Lower	Higher	*In-situ* distribution of rainfall below smaller tanks
3. Water harvesting efficiency	Higher	Lower	*In-situ* harvesting improves efficiency / re-use of drainage water
4. Breaching risks	Higher	Lower	Risk to lower tanks / lands in cascade
5. Seasonality	Higher	Lower	Higher in smaller seasonal tanks
6. Nutrient status	Higher	Lower	Remineralisation & concentration in smaller seasonal tanks
7. Unit construction cost	Lower	Higher	Larger systems more complex and costly to engineer
8. Management complexity	Lower	Higher	Smaller community management groups simplify decision-making.
9. Multiple-use conflicts	Higher	Lower	Higher potential in smaller tanks due to seasonal water supply

Population density is a further significant factor affecting distribution. Based on historic records in different regions, Agarwal and Narain (1998) suggest that the threshold population density for building tanks is around 50-60 persons/ km^2 (population density in NWP averaged 273 persons/ km^2 in 1997; Central Bank of Sri Lanka 1998). This may be one of the reasons why similar structures have not become more established in areas with similar agro-ecology but much sparser population including large areas of Africa (Sreenivasan 1998). The upper population limit varies from region to region, however there is good evidence to show that at high levels of population density, irrigation levels decrease while other functions such as ground water recharge become correspondingly more important (Palinasami *et al.* 1997, Jayaraman 1997). Due to a combination of demographic and physical factors described above, in both Tamilnadu and Sri Lanka there appears to be little potential for significant further impoundment.

In Tamilnadu, since the advent of low-cost pumping technology combined with State subsidised energy provision, lift irrigation has become a popular alternative to tank irrigation. This has had a negative impact on the maintenance and operation of the existing tank resource which traditionally also served an important role in recharging groundwater. The net result has been to promote unsustainable rates of groundwater extraction, soil salinisation and the concurrent formation of groundwater markets which have further marginalised the poor (Sainath 1996).

1.2.3 Watershed management

The watershed is defined as any surface area through which rainfall is collected and drained at a common point, thus forming a single hydrological unit (MYRADA and IIRR1997). It is both a natural ecosystem boundary and a logical unit that integrates the socio-economic and biophysical factors that lead to environmental degradation and food insecurity. Community-based water and land management at the watershed level can lead to increased options for on-farm water management at the individual level (Barr 1998, Pretty 1995). The meso-watershed containing a hydrologically connected series of tanks was identified as the fundamental unit of this research. Further biophysical and socio-economic justification, is presented in Chapters 2, 5 and 6.

Contemporary watershed development revolves around community institutions. These consist of various interest groups relating to resource use, gender, micro-credit etc. that are confederated at the village and subsequently watershed level. Physical components include, sound cropping practices and integrated production systems (i.e. agro-forestry, horticulture and aquaculture). *In-situ* and *ex-situ* soil and moisture conservation includes construction of silt and water harvesting structures. These are also being investigated for their aquaculture potential (Murray and Felsing 1998). Over the last two decades, a huge development initiative in Sub-Saharan Africa and other semi-arid areas of the world has been based on this watershed model with its emphasis first and foremost on 'people's institutions'. The Indian government currently spends some US$300 million on a variety of watershed development programmes in semi-arid areas (Barr 1998).

In Sri Lanka, as in many parts of India, watershed management traditionally existed mainly in the form of the ancient community-managed cascade tank systems.

Management was centred on the division of watersheds around their village tanks into different sections for specific purposes. People had their houses and home-gardens close to the tanks. Land adjoining the village was used for slash and burn (*chena*) cultivation, while forests in the catchment were left undisturbed (Ulluwishewa 1995). There were numerous examples of collective management practices, many of which still persist. These include a flexible freehold form of irrigation known as *bethma* (whereby the extent of household plots correspond with seasonally variable tank storage levels – Chapter 4) and collective fish harvesting / distribution (Chapter 5).

Despite the rehabilitation of large numbers of village tanks under bilateral development programmes over recent decades, there has been no real effort to apply the institutional model of watershed development that has been applied so extensively in neighbouring India to the Dry-Zone of Sri Lanka, although it would seem a logical step. This is perhaps because the area is less marginal in terms of its agro-ecology than corresponding sites in India, and / or perhaps because of a lack of political will. Another possible reason is that a highly developed network of ancient tanks already exists over much of the Dry-Zone, i.e. in the watershed development model, farmer involvement in the construction of physical soil and water harvesting structures is used as catalyst for institutional change.

1.3 Land and water rights

For poor people to benefit from development interventions designed to enhance aquatic production, they must have secure rights to suitable land and water resources. This is especially critical in drought prone areas where water is scarce and storage highly erratic and the degree of security will be a key factor in determining the appropriateness of different technologies. In this section I examine some general characteristics of water rights. I then go on to examine the subset of common property resources which may hold potential for poorer groups including the landless to participate and benefit from aquaculture.

Property regimes define the (1) transferability of resources, i.e. rights to consume, sell, exchange, lease, bequeath and preserve as well as (2) their actual use. The rights which accrue to land and water are key factors which influence the degree of cooperation, mutual investment and collective / communal action expended in their management. At the heart of property rights in relation to water is the fundamental issue of allocation; who should receive how much water, from what source and for what use. Most fundamentally this is about the social relationships between people; rights holders and duty bearers that shape negotiation and decision making (Sakthivadivel, Fernando *et al.* 1996, Meinzen-Dick and Randolph Bruns 2000).

From this perspective, property rights can also be viewed as institutional arrangements of rights and duties which allow us to expect a certain type of behaviour from other members of our society. In other words property regimes define society's collective perceptions about the scarcity and value of a resource. These working rules of interaction whether formal, i.e. legally encoded, or informal; in the form of local norms and customary traditions, describe what individuals can, must, or may not do. They are enforced by collective sanctions and their breakdown can be catastrophic.

In practice, religious and socio-cultural rules, development project rules and unwritten local norms (shared beliefs) exist alongside statutory laws. However, the form that customary rights take is often a direct response to the practical problems faced by communities and very often the resulting access rules are incorporated into local cultural and religious traditions and values. This is a way of ensuring they are widely accepted and adhered to by the local people who share these values and reproduced through successive generations.

Rights associated with water present unusual difficulties and opportunities. Just as the resource is fluid and dynamic so also must be the rights. Customary laws achieve such flexibility through their 'conditionality'. Within wider access boundaries they provision for continuing informal renegotiation of rules in response to changing seasonal and annual climatic factors, external rules and laws and user priorities. Therefore different systems of water rights are not exclusive, but overlapping, always evolving and different sets of rules may apply at different places and times (Meinzen-Dick and Randolph Bruns 2000, Mosse 1997b).

1.3.1 Common Pool resources

Common pool resources are those from which extraction is deductible and it is simultaneously difficult to exclude competing users (IFAD 2002). Rangeland, forests and lakes are common examples. They may be managed in at least four different ways; (1) in an open access manner in which there is no exclusion of users or the extent of extraction/ use (2) as a common property resource (CPR) with well-defined rules of access and extraction by discrete groups of individuals (3) as exclusive (private) individual property or as (4) state or public property.

Common and open access property regimes (OAR) were formerly considered as a single regime often referred to as common pool resources. This view dates back to the seminal 'Tragedy of the commons' (Hardin 1968) which posited unregulated resource appropriation and depletion as the inevitable outcome of all common ownership. However a shift in thinking followed the recognition of CPRs as a 'fourth property estate' overlooked in Hardin's original model. Subsequently it was acknowledged that where there are well defined and tested normative rules of access and extraction, and that sustainable governance is often best entrusted to indigenous organisations (Johda 2001, Ostrom 1994).

CPRs can be defined more precisely as 'private property for the group' where non-members are excluded from use and decision-making, while individuals within the groups have a range of rights and concomitant duties. Built in incentives, economic and relational also serve to re-enforce the system and foster mutually beneficial collective action (MBCA). While CPRs share the subtractibility of OARs it is restricted due to their higher 'excludability' and 'observability' as a result of their smaller size (see below). Management is likely to take place under existing social systems with shared norms & sanctionable customary rules and conflict resolution more likely to take place in low-cost informal local arenas. Whereas multiple-use activities in open access resources are likely to be uncoordinated, activities under CPRs exist in multiple layers with multiple rules. Consequently, the costs of mobilizing resource use under CPRs can be very low. Some of the main preconditions for successful collective action are summarised below (Bromley 1992, Ostrom 1994, Firth 1997, De Castro 1988).

(1) *Resource characteristics:* Suitable resources are likely to be smaller in size with clearly defined physical boundaries.
(2) *User group characteristics:* Communities are likely to be smaller in size and with discrete social boundaries rather than groups dispersed over a large area. The relative

power of sub-groups who favour the commons will be greater than those favouring private or sub-group enclosure. Local forums for negotiation will be well developed. Normative relations will enforce mutual obligations. Enforceable rules and sanctions will exist to deter rule breakers.

(3) *Relationship between user groups and the resource*: The resource will be important to the survival or the user group. The group will possess knowledge regarding sustainable resource exploitation. User groups are likely to live in close proximity to the resource. This and the smaller size of these resources will increase the ease ('observability') with which free-riders can be detected thereby deterring them.

(4) *Technological costs:* These may be higher than open access systems, i.e. costs of exclusion such as fencing

(5) *Relationships between users and the state*. Much will depend on the States will and tolerance in relation to community management and the 'presence' of state institutions, i.e. their distribution, ability to deliver public services and to enforce government policy.

Based on the available literature, most fisheries in Sri Lankan tanks fall into either the open access resource (OARs) or CPR categories (Table 1.3). Smaller village tanks in rainfed areas are most likely to fall into the second domain for fisheries and other uses. The management group comprises the adjacent *purana* community bound by kinship and caste (Chapter 4). Levels of excludability to 'non *purana* members' are contingent on relative priorities accorded to different water uses and the externalities imposed by different uses on each other (Chapter 2). For example, tolerance of external participation is likely to be higher for lower priority uses including fishing, when they do not impose negative externalities on higher priority uses, e.g. irrigation and bathing. Such externalities will be more important during the dry season when tanks reach their lowest levels. Consequently, informal bans are imposed on fishing until intensive collective harvests can be organised (Chapter 5). Although rules are less formally encoded than they were in the past, a strong normative tradition still influences management decisions. These smaller tanks are also likely to be in clear view of adjacent habitation, thereby increasing 'observability' and deterring free-riding.

By contrast, commercial fisheries in major perennial tanks are more likely to fall into the open access category (Table 1.3). As a relatively recently introduced resource (section 1.4) the fishery has never been fully incorporated into any existing social system and there has been an institutional failure to implement effective management with enforceable rules resulting in regular access disputes and conflicts (Murray 2004a).

Table 1.3 Access characteristics of perennial and seasonal tank fisheries in Sri Lanka

Resource	Perennial fisheries in major tanks	Fisheries in seasonal village tanks
Access rights	Open Access (*Res nullis*)	Common Property Resource (*Res communis*) Often with usufruct (i.e. non transferable) rights
Size	Larger	Smaller
Management authority	Absent or broken down	Social unit with defined membership boundaries and some common interests
Management system	Free resource appropriation through self interest, 'capture and control'	Shared norms & sanctionable customary rules
Incentives to participate in resource management	Low	Economic and relational
Participation	Heterogeneous kinship groups or individuals	Relatively homogeneous groups with most individuals affected by operational rules (hence compliance)
Excludability	Low	Excludability determined by membership of community and multiple-use characteristics.
'Observability'	Low	High
Subtractability	Free	By members of community or group mainly
Conflict resolution	Local confrontation and unreliable external agency	Low cost, local arenas
Multiple-use	Uncoordinated	Activities in multiple layers with multiple rules.
Costs of co-ordinating resource use	High	Low
Management outcome	High user rates tend to deplete capital assets	Efficient / sustainable

There is no presumption in this study that collective action is more or less likely to succeed than state regulation or privatisation, but it is clearly preferable to the OAR situation and should be considered as seriously as the other two. Clearly, as population size and demands on a depletable resource increase, many of the preconditions listed above will begin to break down. In these circumstances privatisation or state regulation may still be the only practical means of arresting resource degradation.

Two other very different concerns also underlie the current policy agenda. On the one hand community management is compatible with the current participatory development paradigm which supports indigenous community decision-making over top down technical approaches. On the other hand, it rids the state of an onerous financial burden and an untenable obligation to manage widely dispersed micro-resources such as village tanks. Therefore, while environmental conservation issues can be viewed from a moral perspective they are also unavoidably political. Agarwal and Narain (1998) argue that the current consensus favouring community resource management is an objective sought mainly via policy making rather than through social movements or fundamental transformations of power relations and asset ownership which are more difficult to achieve. They add that 'when communities posses real power to make decisions over the resources they control, their notions of conservation may be radically different from academics, development organizations and governments'.

These observations are underscored by the history of policy and thinking on community in conservation which is one of constant revision. The last 30 years have seen some of the most dramatic changes (Argwal 1997). Only recently resource conservation was equated with protecting resources from people themselves whereas adherence to tradition was viewed as shackling progress. Emphasis was on coercive measures including enclosure of the commons through privatization or state control (Gordon 1954, Scott, 1955, Hardin 1968). This pervasive and ultimately unsuccessful view which resulted in a move from community to more centralized management systems in many countries was seen as an inevitable evolutionary and modernizing process. It held that traditional community property rights did not provide adequate incentives for protecting resources or eliminating externalities in the face of modern state and market intrusions combined with increased demographic and consumptive pressures. However, the 'tragedy of the commons model' failed to recognize the ability of groups of individuals to build more sustainable social arrangements of resource appropriation.

1.3.2 Current concepts in common property and collective action

From a conceptual standpoint the current consensus is supported by contemporary theories of collective action and common property institutions (Berkes and Feeny

1990, Bromley 1992, McCay and Acheson 1987, McKean 1992, NRC (National Research Council) 1986), Ostrom 1990b, Peters 1994, Pinkerton 1989, Stevenson 1991 Wade 1988, Netting 1976). These social scientists examined the relations between resource use and appropriation in local ecological settings. Netting 1976 showed how property regimes are closely related to both the ecological and economic features of the resource, influencing the cost / benefit balance of different forms of appropriation. This 'cultural ecology' approach therefore emphasized the relationships between users and the resource. Subsequent work recognized that the development of co-management systems must consider multiple resource use and the participation of different user groups in a complex political process (Pinkerton 1989, Ostrom 1990a). This became known as the 'political ecology' approach emphasizing the relationship between different users in regard to the resource. Both schools are alluded to in the definition of CPRs given in the previous section.

Mosse 1997a sees theoretical explanations of collective action in common property systems as alternatives to the 'tragedy of the commons' view having taken two main forms. (1) The most recent (like Hardin's model) use game theory in an institutional-economic analysis of cooperative action to derive generalisable principles for farmer managed irrigation. As a tool which can be used to predict under what circumstances 'rational' people will or will not cooperate. A deterministic approach such as this has obvious attractions for development agencies. (2) The second view suggests that cooperative solutions derive not so much from individual rationalism as from a 'moral conscience' based on persistent traditional norms and values. Such norms are seen as arising from a community's collective dependence on local resources and need to manage risk.

Mosse equates these two schools of collective action with two long opposed traditions in social science: one viewing man foremost as a self-interested rational (utility maximising) individual or *homo economicus* (Hobbes 1651, Smith 1776) whilst in the second man is firstly a social being or *homo sociologicus* (Linton 1936, Dahrendorf 1965).

Based on a study of a 'tank irrigated landscape' in Tamilnadu, Mosse (*ibid*) who adopts an ethnographic perspective, criticizes both views as being apolitical and ahistorical. Equilibrium outcomes based on autonomous rational self-interest do not adequately represent the social and political forces acting on traditional systems and behaviour. When considered at all, political forces are seen as eroding tradition rather than as part of a process of change or evolution. Rather than steady-state rule-governed systems based on simply calculated payoffs, Mosse advocates a view of 'historically-specific structures of power which shape changing ideas of property rights and entitlement'. Analysis, he argues, should be extended to include the range of symbolic social interests normally rejected as economically irrational. He views the tank as a public institution like for instance the village temple, expressive of relationships of dominance, dependence and caste rank. The development of the Sri Lankan tank resource is described from such a 'sociological-historical' perspective in Chapter 4.

In the next section I examine some common problems encountered when trying to define what community actually is. Thereafter, I examine the institutional arrangements through which property rights to village tanks are expressed

1.3.3 Definitions of community

Participatory research techniques (Chapter 3) are designed to work at different scales of social and temporal aggregation. In most cases the focus of attention resolves from the fundamental individual or household unit, to broader social assemblages defined by one or more shared social characteristics; gender, age, language, ethnicity, caste etc. A subset of people sharing a number of such characteristics within discrete spatial boundaries often becomes the *de facto* and broadest scale for most research. These groups are then loosely defined as a 'communities'. Despite the central position of community in contemporary participatory approaches, such oversimplification remains the norm.

The vision of small, integrated and homogeneous communities using locally evolved norms and rules to manage resources sustainably and equitably in the absence of state and market interference is a powerful and value laden myth. This notion of the 'village republic' (Phear 1995) has its polar opposite in the notion of the centralized hydraulic state (Agarwal and Narain 1998, Mosse 1997b). The assumptions of the 'village republic' are evaluated below.

(1) Small spatial units with discrete territorial affiliation: Although small size does confer advantages in terms of internal decision making complexity, it also has the serious drawback of reducing the groups negotiating effectiveness with powerful external actors.

(2) Homogeneous social structures: In fact, even where members of a group are similar in terms of caste, kinship, ethnicity, language and religion, differences are still likely to exist in numerous dimensions of wealth as well as intra-household factors such as gender and age. There also exists the possibility of layered alliances which span multiple levels of local politics and social interaction. Participatory approaches which focus on equitable outcomes place great emphasis on understanding wealth differences using tools such as wealth ranking (Chapter 3). Yet attention to all these factors is critical to resource management outcomes that are conflict free and equitable.

(3) Shared interests and norms: serve to prohibit certain kinds of undesirable behaviour, while at the same time promoting cooperative decision making. As such they can be a powerful force in community-based resource conservation. However as discussed above, norms come into being as an outcome of various actions and political process, therefore even when codified they are rarely static. If one uses such norms as a definition of community then one is also faced with a changing notion of community over time. Most critically, norms or shared-understandings are amongst the factors that are least amenable to manipulation through external intervention.

1.3.4 Institutional arrangements for water management

In this section, I examine the potential for building strong contemporary water management institutions based on traditional institutions that are also compatible with the goals of poverty-focused development.

Mosse (1997b) describes how village tank systems in southern Tamilnadu never came into being as autonomous village systems separate from the state, but were always part of a process whereby regional powers extended and maintained domains of control. While this can also be said of Sri Lanka, the collapse of centralised governance in the Dry-Zone zone in the 13th Century (Chapter 4) did subsequently necessitate more autonomous modes of operation. In the interior, scattered communities settled around village tanks sustained life while major irrigation works fell into disrepair. This ‘dark age’ lasted for the next 500-600 years. The history of both countries demonstrates that village institutions responsible for water management respond to social and physical change. Selvaraj (1999) recommends that rather than blue-print solutions based on steady-state models of cooperation there should be close monitoring of on-going struggles in order to strategically support sub-ordinate resource user-groups.

Mosse (*ibid*) observed that indigenous management systems purposefully avoided formal, asset holding ‘corporate-type’ institutions with their high transaction costs and uncertain benefits. Furthermore, rather than democratic decision making, traditional systems supported existing structures of authority and individual status which reinforced gender and caste exclusions. Despite expressions of public ‘agreement’, attempts to establish alternative democratic institutions often simply result in (1) the co-option of the institution by existing leaders with little real change (2) marginalization of the new institution (3) undermining of the new institution by local power brokers, i.e. conflict.

Consequently, external agencies must usually interact in a context of continually contested power rather than a static consensual tradition. The promotion of new democratic institutional arrangements by external agencies supporting subordinate groups can provide the impetus for positive change but also can often unwittingly lead to overt politicisation, tying up development efforts for protracted periods. From a farmer perspective, the main incentive for accepting such innovation is often simply to create a link to external channels of support, whether from private, State or NGO sectors.

Mosse suggests that it is the decline and erosion of indigenous forms of collective action which often makes the appearance of more accountable institutions possible. Indeed, very often successful cooperative institutions are not the expression of enduring institutions of autonomous village government, but an indication of the replacement of indigenous authoritative control.

Finally he observes that moral claims for expenditure on ‘culturally defined public goods’ (temples, festivals etc.) is high and penalizes collective investment for production (including tank system maintenance) and collective entrepreneurial activity. This may be a less significant factor in the context of Sri Lankan Buddhist communities. Although here too tanks are imbued with 'symbolic capital', there is less internal stratification along caste and religious lines (Chapter 4) and so perhaps there is greater potential for the emergence of consensual outcomes.

Agarwal and Narain (1998) stress the role of external actors in local communities which rarely if ever operate in isolation. They suggest that community-based management is about shifting power between these actors and should be based on principles of checks and balances on the various parties; local groups, government and even NGOs. Unchecked authority is equally damaging in the hand of any party, though greater real authority still needs to be transferred to the community. Federated structures of community groups, i.e. water-users groups federated at watershed level are able to negotiate with external parties on more equal terms, but must be accountable and democratic if they are to justly represent their constituents. Finally they recommend that the focus of community-based conservation must be on implementing 'reasonable processes of decision-making rather than guaranteed outcomes', i.e. decision makers must be performance reviewed, marginal groups represented in decision making and current decision processes should feed into future ones.

Wanasinghe (2001) recommends that government assistance to local collective action should take the following forms. (1) Provision of a supportive legal framework recognising local organisational identity through legal rights; the state will become the enforcer only in the last resort (2) Provision of technical assistance which can improve the knowledge base and enhance sustainability (3) Provision of credit in the form of loans and grants rather than direct infrastructure / maintenance intervention.

1.3.5 Multiple-use issues

In addition to their primary irrigation function, village tanks are used for a range of ancillary purposes for which users come both from within the immediate and from adjacent communities. An understanding of reciprocal access arrangements for different uses, the extent to which unilateral arrangements are tolerated and the nature of negative externalities which different uses impose on each other is critical. Most fisheries stocking programmes in the past ignored such issues, resulting in conflicts which became a significant factor in their recurrent failure (Murray and Little 2000c). These issues are considered in greater detail in Chapter 2: section 2.3.1.

1.4 Demand for inland fish, history and current status of freshwater aquaculture in Sri Lanka.

1.4.1 Demand for inland fish

Fish products represent the major source of animal protein in the Sri Lankan diet (Jinadasa 1977). An estimated 96% of the population regularly consume some form of fresh or processed fish (Sugunan 1997), which constituted between 57.3 – 64.7% of total annual non-vegetable protein intake between 1991 and 1995 (NARA 1999). Nathaniel and Silva (1998) suggest that this figure rises to as much as 85% of protein intake in rural areas. Over the same 5-year period, meat consumption contributed only 10.5 – 15.8% of animal protein intake, while eggs and dairy products, much of them imported, constituted the balance of 23.8 – 28.9% (NARA *ibid*).

Mean *per capita* consumption of fish products rose steadily during the 1980’s to a peak of 18.6kg, fluctuating between 12 - 16kg *per capita* over the following decade. One of the highest levels of any of the developing countries in the region; this reflects Sri Lanka’s rich endowment of marine and inland water resources and culture of low livestock holdings / consumption (NARA 1999). However Sri Lanka has never been able to exploit its fisheries resources in a manner capable of meeting internal consumer demand. Net fish production in Sri Lanka (local fish production minus export production) was sufficient to meet only 53%-78% of annual consumption during the 1990’s. As in the past, the deficit is filled with imports of processed fish; mostly dried / salted marine fish and lesser amounts of canned fish (Hornell 1904, De Silva 1949, Jinadasa 1977).

Although production is dominated by the marine sector, there are marked spatial variations in consumption patterns. Demand for more costly marine fish is concentrated in urban areas as well as coastal production areas and the arterial routes between production and urban areas. In rural inland areas of the Dry-Zone, demand is predominantly for cheaper, locally available inland fish supplemented with dried marine varieties (ARTI 1998-1999), Key informant interviews, St Johns Market Colombo, Central market Kandy and rural markets in North Western, North Central and Southern Provinces). Appendix 1 shows the importance of the abundance of large perennial reservoirs supporting commercial fisheries in the field research areas.

Much of this demand is based on an exotic fish species; following their introduction in the early 1950's, tilapias rapidly colonised most of the countries fresh and brackish water resources with little additional effective government intervention other than the provision of subsidised gears and craft to exploit the fishery. While no reliable figures are available, inland yields rose exponentially to reach an estimated 30-40,000 tons annually by the late 1980's. Today, tilapias constitute some 95% of total landings and it would appear that only the resilience of the exotic tilapia to the gill net fishery is arresting rapid resource depletion as the number of entrants and intensity of fishing methods increases. Meanwhile catches of indigenous species have declined dramatically (Murray 2004a).

It is reasonable to assume that through provision of a quality, low-cost and reliable fresh animal protein source to accompany the rice staple, the rise of the tilapia fishery has supported the simultaneous repopulation of the Dry-Zone (Chapter 4). Yet for other reasons discussed in Chapters 5 and 6; this significance remains under-represented by official statistics.

1.4.2 Historic trends and poverty-focused options for aquaculture

Sri Lanka had no tradition of aquaculture or an organised freshwater fishery until very recently, although there is evidence that a minor subsistence fishery existed from historical times (Ulluwishewa, 1995; Siriweera, 1986). Aquaculture research and development began in earnest only during the last three decades. This has been characterised by a marked technical bias, driven more by the requirements of successive donors than farmer needs or market opportunities. Consequently, there has been no sustainable uptake.

The subordination of technically driven agendas to a more people-centred and needs-based approach reflects a recent move of research and development resources away from the 'development of aquaculture' towards strategies promoting 'aquaculture for development' (Edwards 2001), i.e. with the goal of assessing the potential contribution that aquaculture might make to sustaining rural livelihoods.

Low-input enhancements (section 1.4.3) that give an appropriate balance between investment in individual effort and profit also hold greater promise for sustainable poverty-focused aquaculture. Conversely, more intensive grow-out options are unlikely to be sustainable for the following reasons:

- Risk of financial losses associated with erratic environmental conditions.
- Returns to individual effort are often uncertain in CPR access regimes.
- Intensive production is more likely to result in externalities and conflicts with alternative water users.
- Unlike most other countries in South Asia, Sri Lanka lacks any tradition of aquaculture, i.e. rather than adapting to the existing socio-economic, cultural and educational setting, intensive interventions will be novel / transformational and therefore less adoptable.
- High value outputs produced in bulk are more likely to be expropriated by relatively better-off groups resulting in conflicts

For these reasons, an adaptive rather than strategic approach was adopted in the design of action-research interventions. In other words emphasis was on helping farmers to adapt and adopt existing technology rather than implementing novel ‘transformational’ technologies.

A brief review of stocking options and their history in Sri Lanka is given in the following sections. The potential for different enhancement techniques was also canvassed during preliminary primary and secondary stakeholder forums (Chapter 7, section 5.3).

1.4.3 Stocking enhancements

In a spectrum of production intensity ‘enhanced’ fisheries occupy the space between natural capture fisheries and semi-intensive aquaculture. Rothius (1993) defines enhancement as the ‘manipulation of the existing fish population, and or optimalisation of the aquatic environment for improved fish production in a natural or man-made water body’.

Environmental modifications fall into two overlapping categories; physical and nutritional. Physical modifications may be designed to facilitate fish migration / recruitment or conversely to reduce the risk of losses from culture-based production systems. Modifications can be designed to promote habitat diversity, i.e. for breeding and feeding requirements or in the case of seasonal water bodies to provide refuge during the dry season. Nutritional status can be enhanced through addition of fertilisers to stimulate primary productivity. Instead of reliance on costly feeds and fertiliser's characteristic of more intensive aquaculture, this might be achieved through manipulation of existing on-farm resource flows, i.e. adjustment of livestock grazing patterns.

The manipulation of species composition is based on the selective removal of 'undesirable' species (i.e. relative to the main production goals) or more commonly, on the stocking of favourable lacustrine species. Stocking is most useful for management of smaller water bodies where there is a need to compensate for low natural recruitment, or disruption of recruitment in the case of seasonal water bodies (Rothius *ibid*). Conversely, stocking is usually not economical in larger bodies of water where very large numbers of fish must be stocked to achieve a balance between stocking and recapture, or where natural reproduction of a variety of species occur (Welcomme and Hagborg 1977). In such cases continuous restocking is only practiced when the species is of great value (e.g. salmonids), or the juveniles do not require an expensive high protein diet (e.g. exotic carps)

While stocking enhancements are widely practiced as components of development programmes, outcomes are very rarely adequately documented contributing to a poor record of sustainability (Welcomme and Bartley 1988, Cox 1988). This is, in large part, a consequence of the scale and spatial and temporal dimensions of resource extraction associated with such efforts.

1.4.4 Production potential in inland water bodies

The unusually high primary productivity of Sri Lanka's shallow lowland reservoirs (section 1.4.6.1) makes such water bodies potentially ideal for extensive fish culture based on stocking enhancements. To give some idea of production potentials, the maximum sustainable yield (MSY) for perennial Sri Lankan reservoirs is estimated to be 256 kg ha^{-1} yr^{-1} (De Silva *et al* 1991). This compares to an average productivity of less than 10 kg ha^{-1} prior to the introduction of tilapia in the 1950's while average yields from carp based perennial reservoir fisheries in India and China are only 15-150 kg ha^{-1} respectively (Haylor 1996, Oglesby 1981). Unlike these countries, Sri Lankan perennial reservoirs are managed mainly for their self-recruiting tilapias. Stocking is therefore only necessary in seasonal waters (section 1.4.5). In early trials using polycultures of tilapias and exotic carps in seasonal tanks, yields of 120kg to 2.3 mt ha^{-1} (mean 820 kg ha^{-1}) in a single growing season were reported (Chakrabarty 1982). However, as will be discussed below, the mean yields cited for these water bodies mask extremely erratic outcomes where loss making situations are common (section 1.4.6.2).

1.4.5 The dynamics of stocking and yield

In Sri Lanka attempts to produce yield predictive models for fisheries management including the optimisation of stocking regimes, have been restricted to perennial systems (Pet 1996, Amarasinghe 1998). These range from population models to empirical correlations of yield with measures of the potential productivity of water, e.g. morpho-edaphic indices, specialized indices based on benthos or zooplankton, densities and catchment land use characteristics (Amarasinghe and De Silva 2004). Lorenzen (2000) has developed more realistic yield models for small water bodies based on work in SE Asia, which interpret stock recruitment, mortality and critically, growth relationships which allow for interaction between native and stocked fish, i.e. multi-species fisheries. However, no reliable models have been developed for the smaller village tanks which are the subject of this study; probably as a result of highly erratic environmental conditions associated with their seasonality (Murray 2004b).

The parabolic profile of Sri Lanka's lowland tanks results in much more complex seasonal hydrological profiles compared to straight-sided impoundments, i.e. such as excavated ponds in which surface area tends to remain relatively constant throughout the culture cycle. This makes generalisation of simple stocking recommendations based on area or volume characteristics even more problematical. Most current recommendations relating to stocking of hatchery-produced carps are based on a crude median value, i.e. 50% of the water-spread area obtained at full supply level (FSL). Using this measure the Government of Sri Lanka (GoSL) Ministry of Fisheries recommends a density between 1,500 and not exceeding 2,500 fingerlings ha^{-1} using equal numbers of available species with complementary i.e. non-overlapping feeding habits, as a very general rule of thumb.

Empirical studies in perennial reservoirs have revealed some general relationships between stocking regimes and yield outcomes for carps. Strong inverse relationships between reservoir area and yield per unit area demonstrated in China (Li and Xu 1995), Sri Lanka (Amarasinghe 1998) and Mexico (FAO 1993) are mainly due to the unrealistically high number and cost of fingerlings required to ensure good recovery rates in larger reservoirs. Amarasinghe (*ibid*) found the optimal yield for a mixture of carp species in a regulated gill net fishery using non-intensive fishing practices is only 30 kg ha^{-1} yr^{-1}. This compares very unfavourably with the average yield of the self-recruiting tilapia fishery (i.e. around 256 kg ha^{-1}) for which yields are positively correlated with (perennial) reservoir area (De Silva 1988a). Amarasinghe (*ibid*) concluded that stocking should be limited to smaller reservoirs, certainly no greater than 800 ha, above which catch per unit effort (CPUE) rapidly declines. Creech *et al* (*ibid*) found that even in smaller tanks (20 – 39ha) carp enhancements failed when they were likely to interact negatively with existing artisanal tilapia fisheries, i.e. resulting in the premature harvest of juvenile carps.

1.4.6 Species selection

Suitable species for stocking seasonal tanks should be able to utilise naturally available food resources within the tank and reach an acceptable size for local consumers within 6-8 months. Zooplankton species diversity and abundance is low in Sri Lanka (De Silva. 1988b) indicating that phytoplankton specialists will perform best. Unfortunately, few candidates exist in the indigenous fauna and the choice is essentially between several exotic varieties of carps and tilapias. Tilapias are self-recruiting and so less reliant on costly hatchery facilities. While the carp varieties require continual restocking of hatchery produced juveniles they are faster growing and likely to yield a more marketable product than tilapias grown in seasonal tanks (Murray 2004a). The technical potentials of these two groups along with a number of indigenous candidate species are compared and contrasted in the following sections.

1.4.6.1 Tilapias

The ability of tilapias to rapidly colonise and thrive in a diverse range of aquatic habitats has been attributed to their highly adaptable reproductive and feeding habits along with their tolerance of a wide range of adverse environmental conditions. The following additional factors have contributed to their remarkable success in Sri Lanka.

(1)The shallow morphometric characteristics of Sri Lankan reservoirs and high turnover rates involving the periodic drying of vast draw-down areas grazed by domestic animals enhances nutrient cycling. This results in unusually high primary productivity and fish-yield potentials (De Silva. 1988b).
(2)Tilapias have the ability to adapt to a wide range of feeding niches low in the food chain. They can shift between zooplanktivory and detritivory and therefore exist as column filter feeders or benthic-bottom feeding omnivores (Coward and Little 2001). Unlike endemic species, they also have the ability to utilise the abundant blue-green algae populations found in Sri Lanka's lowland reservoirs (De Silva *ibid*). They are also opportunistic predators of small fish.
(3) The shallow profile of lowland reservoirs also increases the availability of marshy littoral areas suitable for nesting and lessens the impact of frequent level fluctuations on nesting sites compared to steeper-sided impoundments.
(4) The ability of tilapias to breed within a wide size range has become a critical advantage in the face of increasingly intensive fishing pressure (De Silva *ibid*).

Since its introduction in 1952, *Oreochromis mossambicus* has become the most successfully established exotic species in Sri Lanka. However, since the late 1970's *O. niloticus* has become the favoured species for stocking programmes, because of its superior growth characteristics and body conformity.

Introgressive hybridisation of these two populations has now occurred in most reservoirs. There is evidence that this leads to an imbalance in sex ratio in favour of males resulting in reduced fecundity (De Silva 1988a Amarasinghe and De Silva 1996). The net impact of the introduction of *O. niloticus* on the fishery is as yet un-quantified, as the gains to be had from further stocking in larger water-bodies which already contain self-recruiting populations of *O. mossambicus* is difficult to assess.

Fishing pressure on larger individuals is also likely to reduce average harvesting size, whilst predation pressure on juveniles will increase it (Pet and Piet 1993). In a detailed study of Tissawewa, a small perennial tank, Pet (1996) found that the mean size of *O. mossambicus* at maturity had decreased from 16 to 13cm in recent years at the same time as fishing pressure had increased. Meanwhile, Sugunan (1997) argues that the highest production can be achieved if fish are caught at the minimum marketable size as long as this does not fall below a threshold size which impairs self-recruitment.

Under non-limiting conditions tilapia growth rates are intermediate between the better and poorer performing carp varieties (section 1.4.6.2), however De Silva. (1988b) argues that a propensity to breed at a small size at high stocking densities can make tilapia unsuitable for stocking in seasonal reservoirs. Under such conditions, the relatively faster growing *O. niloticus* might yield larger sized fish within narrow production windows. Chakrabarty (1982) reported production levels between 440 and 550 kg ha^{-1} yr^{-1} after stocking seasonal tanks (5-10ha) with *O. niloticus*. However, in a series of carp stocking trials in 15 seasonal tanks Chandrasoma and Kumarasiri (*ibid*) recorded by-catches of *O. mossambicus* from 0.4 to 408 kg ha^{-1}. These stocks had entered naturally through adjoining waterways and in many cases their yields were greater than those of the stocked species. Although erratic these results indicate that enhancements based on locally sourced wild seed could reduce or remove dependence on hatchery production.

Although *O. mossambicus* reproductive activity peaks during the rainy seasons at the same time as most indigenous species, it also spawns readily throughout the rest of the year when environmental conditions are favourable. The preferred habitat of *O. mossambicus* larvae is the shallowest part of the littoral zone (Pet 1996) especially those parts with vegetation and a detritus layer. Seed survival is lowest during the dry season when little vegetation exists around the littoral zone and predation pressure is higher.

1.4.6.2 Exotic carps

Early introductions of exotic carps were intended to supplement tilapia production in perennial reservoirs through exploitation of complementary feeding niches. Carp fingerlings were stocked into Sri Lankan reservoirs between 1968 and 1981 but only began to enter catch statistics at low levels in 1983 (De Silva. 1988b). Today, the poor returns on these investments have lead to some commentators discrediting carp stocking programmes in general (Fernando and Gurgel 2000).

During the 1980's focus shifted to stocking seasonal tanks, long perceived as having unfulfilled potential with respect to fish production. Numerous trials were undertaken to investigate the potential for polycultures of fast-growing exotic carps. Chakrabarty (1983), Tennekoon and Nanayakkara (1982), Thayaparan (1982), Chandrasoma and Kumarasiri (1986) and Balarin and Hatton (1979) have reported on the outcomes of these efforts. Seven species were utilised, four Chinese carps: common (*Cyprinus carpio*), bighead (*Hypophthalmichthys nobilis*), Silver (*H. molitrix*), grass carp (*Ctenophyaryngodon idella*) and three Indian major carps: Catla (*Catla catla*), mrigal (*Cirrhinus mrigala*) and rohu (*Labeo rohita*).

Although these trials demonstrated high production potential, results were extremely variable between reservoirs, successive years and species combinations. One of the most comprehensive incorporated 157 seasonal tanks between 5 to 20ha stocked over four years from 1979-1883 (Chakrabarty 1983). Production averaged 203 kg ha^{-1} yr^{-1} over the entire period, but whereas one tank yielded 2,594 kg ha^{-1}, 51 of the other tanks were emergency-harvested or abandoned entirely due to a combination of drought, floods and poaching. Chandrasoma and Kumarasiri (1986) reported yields ranging from 220 to 2300 kg ha^{-1} with a mean of 892 kg ha^{-1} for 2-5 species polyculture combinations stocked in 15 community-managed tanks harvested after 7-10 months.

Many reports also fail entirely to mention the contribution of natural production to overall stocking outcomes. Mendis (1977) estimated mean natural productivity levels for semi-seasonal village tanks of between 50-150 kg ha^{-1} yr^{-1}, i.e. only slightly lower than the mean level reported in the first trial cited above. De Silva. (1983) suggests a return of 35-40% of the stocked number is required to make a stocking programme viable. In reality rarely are more than 20% of even the most durable varieties recovered (Chandrasoma 1986, Creech *et al.* 2001, Ahamed 2002).

Stocking of grass carp has been suggested as means of controlling problematic aquatic macrophytes such as *Salvinia molesta* (Appendix 23). However poor seed availability, their susceptibility to predation and the large size they must reach to utilise such food stuffs (18-24 cm) have curtailed their use in seasonal tanks.

Bighead and common carp have demonstrated the fastest growth potential. Production data presented by Chakrabarty (1983), Creech *et al.* (2001), and Ahmed (2002) indicate mean specific growth rates (SGR) slightly above 2% during a 6-8 month grow-out period. The other carp varieties typically grew at around only half this rate or less. Unfortunately, common carp, grass carp, silver carp, catla and mrigal juveniles are particularly vulnerable to predation, especially in shallow seasonal tanks where large populations of snakehead (*Channa striata*) persist (section 1.4.6.3). In seasonal tank composite culture with common carp, grass carp yielded only 8 to 64 kg ha^{-1} yr^{-1}, with stocking densities as high as 5,000 ha^{-1}. Conversely bighead carp and rohu (*L. rohita*) show the lowest mortality rates and demonstrate yield outcomes that correlate more closely with stocking rates.

The combination of growth and survival characteristics described above, means that bighead consistently outperforms all other carp varieties by substantial yield margins. Chakrabarty (1983) reported over 1 mt/ha bighead yields in composite polycultures. Creech *et al* (*ibid*) reported that bighead constituted 46-78% of the catch by volume, from polycultures based on bighead, rohu and common carp stocked in 3 tanks (6-12ha). Although most individuals reached a good marketable size (0.5-2 kg), Creech (*ibid*) also observed that farmers were disinclined to restock bighead due to adverse consumer perceptions relating to its oily flesh quality and low market price. Rohu occupies an intermediate position below bighead / common carp and the other carp varieties in terms of growth potential.

Seed availability is a fundamental constraint. Available statistics indicate that despite extensive investment in hatchery facilities, exotic carps have never been produced on anything like a commercial scale in Sri Lanka. Less than nine million carp fry / fingerlings were stocked over the 12-year period between 1968 and 1980 (Thayaparan 1982). The rate increased substantially to 5 million in 1982 and ultimately to a maximum of 10 million fingerlings in 1989 when at least 11 government breeding stations were in operation (NARA 1998). Despite the dramatic increase these levels are still indicative of a poorly planned stocking programme and / or inability to spawn and nurse fry and fingerlings consistently with available resources.

While biologically, the penalty of high mortality acts against stocking of fish at too small a size, the exponentially increased cost of stocking material with increasing size, still tends to favour stocking early life stages. Li (1988) and Tennekoon. (1988) recommend stocking advanced fingerlings at least 10cm in length to reduce juvenile carp mortality and exploit short grow-out periods in seasonal tanks. However due to lack of hatchery nursing capacity the use of 2-3cm fingerlings remains the norm. This is a frequently cited reason for the failure of stocking interventions. The usual practice in carp-based enhancements is to stock as soon as possible after major spill events to reduce the risk of escape followed by a single intensive collective harvest after irrigation requirements have been met.

An alternative strategy applied in this study involved the stocking of more predator resistant locally sourced broodstock for *in-situ* fingerling production. Although this offers a smaller growth window than the use of advanced fingerlings it may still be more cost effective. Managed prey / predator culture systems could also increase yields of self-recruiting tilapias by inhibiting stunting while producing a valuable by-catch.

1.4.6.3 Other indigenous species

A common course in the past has been to promote aquaculture to increase protein production through exotic introductions often at the expense of local bio-diversity. *O. niloticus* for example has been introduced to over 100 tropical and sub-tropical countries including Sri Lanka (Coward and Little 2001). Although it is generally believed to have had no negative impacts Kottelot and Whitten (1996) suggest this is more indicative of the lack of any critical monitoring.

Until the 1970's the population of larger indigenous cyprinids: *Labeo porcellus*, *L. dussumieri* and *Puntius sarana* still supported a fishery in Dry-Zone reservoirs. Since then *L dussumieri* has also declined dramatically while the status of *L. porcellus* has become critical (Pethiyagoda 1994). Pethiyagoda (*ibid*) attributes this to direct competition with tilapia while Pet (1996) concluded that the decline of this and many other indigenous reservoir species is mainly an indirect consequence of the increased fishing pressure using gillnets which followed the introduction of tilapia. The latter contention is supported by the healthy indigenous populations which still exist in war affected areas where fishing pressure is low (pers. obs.). Despite this impact, the tilapia fishery has contributed to rural food security in such a comprehensive manner while keeping pace with rising population that it is difficult to conceive of the situation that would exist without it. Nevertheless, these introductions took place on an *ad hoc* basis and the net benefit has been more the result of luck than design. Furthermore, it is impossible to say what the longer-term impacts of bio-diversity losses might be.

De Silva (1988b) estimates that fifteen fish indigenous varieties recorded in reservoirs are regularly consumed while only six are caught in significant numbers (Appendix 33). These species represent the basis for stocking selection. Desirable production characteristics for seasonal tank culture include (1) predominantly phytophagous feeding habits; blue-green and zooplankton abundance are respectively low and high in Sri Lankan reservoirs (2) the ability to survive and grow well in the harsh conditions common in upper-watershed areas during the dry season (3) the ability to self-recruit under such conditions will also increase potential for low input culture systems. Persistent varieties combine many of the so-called ‘blackfish’ characteristics (Chapter 2): ambulation and air-breathing, resistance to desiccation, tolerance of extreme physio-chemical water qualities, *in-situ* breeding ability etc. However, most are also restricted in size. Only the tilapias, snakeskin gouramy (*Trichogaster pectoralis*) and one secondary consumer, snakehead (*Channa striatus*) are both relatively abundant and capable of growing more than 15cm in length. As the smallest species are less marketable, polycultures of the former varieties became the basis for stocking trials in this study.

The larger indigenous cyprinids are more rigidly potadromous, i.e. they must migrate to their natural riverine habitats during the spawning season and occur naturally only in larger perennial reservoirs (Fernando and Holcik 1991, De Silva 1993). *L. dussumieri*, which is a phytophagous benthic detrivore, has been investigated for its culture potential in seasonal tanks. Although induced breeding is straightforward with good fry survival rates, its slow growth rate (300g per annum) makes it a poor candidate. Chakrabarty (1983) also reported poor growth and survival resulting from trials based using both *L. dussumieri* and *P. sarana* in seasonal tanks.

The simplest low input system tested in the current study would involve the simultaneous introduction of tilapia and snakehead juveniles in smaller seasonal tanks where resident stocks have been mostly or entirely eliminated due to tank drying episodes. This technique would target predation on successive tilapia generations rather than the parental stock thereby maximising production in short growing-windows. In such a context achieving precise prey-predator ratios would be less critical.

Persistence of smaller indigenous varieties, especially the minor cyprinids: *Rasbora dandonicus*, *Ambylpharyngodon melettinus* and several *Puntius* spp., together with juvenile tilapia as prey species, is likely to increase valuable by-catches of snakehead. Such a system is likely to have a benign or positive impact on bio-diversity. This contrasts with exotic carp culture systems where resident populations of indigenous fish are often eliminated to reduce predation losses.

Snakehead (*Channa striatus*) was identified as having high potential for prey-predator polyculture with tilapias. Floating eggs laid in a nest of emergent weeds, hatch after 1-3 days. The fry turn bright orange after a few days and shoal together for around one month during which they are attended by their parents. They attain a length of 1.5cm in two months, lose their orange colour and finally migrate to deeper water. Pethiyagoda (1991) reports that they appear to breed throughout the year, though in the current study nests were most abundant after spill events during which time adults migrate upstream to more seasonal tanks.

Welcomme and Hagborg (1977) note that a considerable proportion of juveniles can be removed from fluctuating systems such as floodplain fisheries where there is considerable overproduction of 0+ cohort fish. The collection of small numbers of fish and fry from local shallow reservoirs with comparable ecological characteristics, for stocking purposes, should therefore have negligible impact on the donor sites.

1.5 Background to the research areas

Sri Lanka (5-9^{o}N; 79-82^{o}E) is a tropical island lying 50km to the southwest of Peninsular India. It has an area of 65,525 km^2 of which 32,000 km^2 are under permanent or shifting cultivation. The surface configuration comprises a south central highland massif rising to 2554m, surrounded by a zone of upland ridges and valleys at a lower elevation. This is surrounded by an extensive plateau of flat or gently undulating lowlands. Three climatic zones, the Wet, Intermediate and Dry-Zone are defined by this topography. The Lowland Dry-Zone (LDZ), which is the wider focus area of this project lies entirely below 300m and covers some 70% of the total land area.

Rainfall in the Dry-Zone ranges from 625-1900 mm p.a. unevenly distributed over two growing seasons, with 60-70% falling during the *maha* season (late September to February) and 20-40% falling during the minor *yala* cultivation season (Late February to June). These seasons are associated with the arrival of the Northwest and the Southwest monsoons respectively. Two drought periods occur during the inter-monsoon periods between February to May and August to October. Rainfall is highly erratic with the co-efficient of variance for annual rainfall during the last 15 years ranging from 20-33%. Inter-annual variability has been shown to be greatest during the *maha* season (Yoshino 1983) and severe drought events associated with the failure of the NW monsoon re-occur on average every 3-4 years in the Dry-Zone. Three consecutive drought years were experienced from 1981 to 1983 and isolated events occurred in 1991 and 1996 (Chapter 2).

The Dry-Zone has been divided into five agro-ecological regions (AERs) regions, where a unique combination of climate, soil and relief give rise to particular farming systems. The Dry Low Country 1 (DL1) zone is the most extensive, covering nearly 50% of the countries total land area (Figure 1.2). It is characterized by annual rainfall levels of 775mm or more (75% probability) and undulating terrain with rocky outcrops (inselbergs). Shallow lateritic reddish brown earths (RBEs) predominate in the higher aspects of the undulating landscape, giving way to more productive low humic gleys (LHGs) in lower depositional areas.

For administrative purposes the country is divided into nine Provinces composed of 25 districts, which are the principle units of local government (Appendix 2). There are between 60 to 150 Divisional Secretariats (DS) within each district, each of which contains from 30-40 *Grama Niladhari* (GN) divisions which in turn represent around 4-8 villages. There are 2-3 *Samurdhi Niyamakes* per GN Division; salaried officers responsible for implementing the Government's social welfare programme. *Samurdhi Niyamakes*, together with the Agrarian Services Department (AGS – the line agency with responsibility for minor tanks and agricultural extension) operate through *Pradeshiya Sabhas* or rural councils. Although even this lower tier of public servants is frequently elected on political patronage, most come from the communities which they serve and therefore remain incentivised to provide good service. Consequently, they represented important points for village entry and future collaboration in this study.

An important factor contributing to the persistence of poverty in developing countries are political structures that render poor people powerless (Hasnip 1999). Over the post-independence period, numerous centralized political and administrative institutions were created with ideological dedication to manage the delivery of public goods and services. However, unresponsive to change as they were, many have collapsed under the evolving demands of a growing and literate citizenry. Simultaneously, increasingly centralised governance has undermined traditional community-based institutions and impeded the emergence of effective new ones. Growing negativism and alienation of the public towards the processes of governance have contributed to recurrent civil wars sponsored by disaffected youth (Gamage and Watson 1999, Bush 2003, Ghosh 1990).

The population of 18.7 million persons consists of three main ethnic groups; Sinhalese (74%), Tamils (18%) and Muslims (7% - DCS 2001). The population of the project areas in North West and North Central Provinces were predominantly Buddhist Sinhalese. Nearly 80% of the total population live in rural areas and of this number approximately 73% are directly dependent on agriculture or seasonal agricultural labour activities. The principle-irrigated crop, paddy is grown on nearly 600,000ha of land (i.e. 18.8% of the total cultivated area) and 38% of this total is under rainfed village tanks. Another 8% work in the commercial fishing industry, mostly in the marine sector (Jayawardene *et al*., 1998. Wilson 1998 Central Bank of Sri Lanka 1998).

Livelihoods are dominated by small-scale crop production, subject to marked seasonality in food availability, prices, income and employment opportunities, credit requirements and health (Appendix 1). Farming activities in the rainfed areas under study are limited to dry-land agriculture (typically 0-1ha) and smaller irrigated areas (90% of plots less than 0.4ha). Paddy (the staple food along with fish) is the principal irrigated crop. Traditional slash and burn cultivation continues to be widely practiced in dry-land areas despite ever-shorter rotation cycles making this practice highly unsustainable. Vegetables and other cash crops are also grown in small home-gardens. Livestock production accounted for only 11% of agricultural output and 3% of GDP in 1984 (Agrawal *et al.* 1987) and holdings are declining further due to a combination of reduced pasture availability, farm-mechanisation and increased off-farm labour opportunities. Based around small-scale irrigation tanks these systems together occupy nearly two thirds of the Dry-Zone cultivated land area and comprise of some of the smallest and least productive land holdings.

Most families supplement household income through seasonal labour migration or remittances from family members engaged in formal employment. The greatest opportunity for local off-farm labour exists under recently developed major irrigation schemes which generally enjoy higher yields and larger individual land holdings. Straddling North Central Province is the Mahaweli H irrigation system (Appendix 8), part of the Mahaweli development programme initiated in 1975 to relieve population pressure in the populous hill country. Many better-off farmers in adjacent rainfed areas, including our main research site, had acquired plots in this system, while others share crop and poorer farms work as agricultural labourers. These developments represent the most significant infra-structural development in the project areas in recent times. They have also necessitated extensive road developments as well as construction of new service centres and markets (UNDP 1998).

Farmers also resort to a number of illicit activities including logging, poaching wild game, crop stealing, brewing liquor and the leasing or sharecropping of land allocated to farmers settled under major irrigation developments. The recent encroachment of extensive areas of forests which once covered the Dry-Zone has also resulted in increased conflict between cultivators and marauding wild animals; especially residual elephant populations (Rudran 1990, pers. obs). This imposes particularly serious agricultural constraints on communities located in remoter upper-watershed areas.

Prior to 1977, farmers benefited from assured markets and high production subsidies under a centrally planned economy which stressed self-sufficiency in food production but stifled economic growth (Weragoda 1998). These benefits, along with protectionist exchange controls and import quota restrictions, were gradually abolished as part of a liberalisation process which aimed to encourage greater market orientation and efficiencies amongst producers (Kodithuwakku 1997) and export orientated economic growth (Kelegama 1999). Although these policies have resulted in a steady rise in GDP (6.4% in 1977), the majority of poor farmers with small seasonal surpluses have poor access to emerging free markets (Sinathamby and Noguchi 1997, Narapalasingam 1999) and have received few benefits. Consequently, they still adhere to traditional subsistence orientated production strategies emphasising household food security and eschew cultivation of potentially more lucrative cash crops that are also more water efficient (Gunawardene, Peradeniya University Extension Specialist, pers. comm.).

Although agriculture still provides the base for local food security, many farmers express a desire to move away from increasingly marginal and high-risk farming activities to the security of waged labour. High unemployment amongst well-educated youth is recognised as a critical problem, contributing to the country’s high suicide rate (HDR 1997). This group has rightly become a focus for development efforts amongst state and non-governmental organisations.

1.5.1 Human development, poverty and malnutrition in Sri Lanka

Amongst South Asian states Sri Lanka is widely recognised as a welfare model (Library of Congress 2000). Its distinctive post independence pattern of development with its emphasis on human capital has resulted in literacy rates of over 90%, mean life expectancy of 73 years and a spectacular reduction in infant mortality. Gender differences are low in both these respects which compare favourably with industrialised nations. For these reasons Sri Lanka has long held middle Human Development status (UNDP 1997) despite a poor record of economic development.

Yet these favourable indicators hide wide sectoral and regional disparities. The core of the absolute poor, i.e. households that spend more than 90% of their earnings on food (Sinathamby 1998) in Sri Lanka has remained at around 25-30% of the total population since the early 1970's, whilst relative poverty has grown sharply (Sinathamby *et al* 1998, ESCAP 1997). This reflects a failure of all policies, including those implemented under economic reforms to reduce poverty levels.

Poverty remains largely a rural phenomenon. It is estimated that nearly half those below the poverty line in Sri Lanka depend on agriculture for their livelihood and another 30% on non-agricultural rural activities (Datt 1997). Rural households tend to have fewer years of schooling, lowest literacy levels, higher dependency ratios, lower rates of participation in the labour force and significantly higher rates of unemployment. Households relying on agriculture as a primary livelihood activity exhibit the highest poverty levels (Sinathamby and Noguchi 1997, Datt 1997). Low-caste groups and farmers settled in rainfed upper-watershed areas are amongst the most disadvantaged of all groups (Murray and Little 2000c).

High malnutrition levels also persist amongst large sections of the rural community. Sri Lanka records the fourth highest rate of underweight births (20%) in the world (UNDP 1997), while 36% of pre-school children are stunted. These levels are increasing once again, after food based government welfare was recently replaced with income-based relief (UNICEF, 1997; quoted in Gunasekara 1996). De Silva (1991) estimates mean individual daily protein intake is only about 28g compared to a recommended intake of 45g.

1.6 The Research Framework

The research framework adopted for the entire study is shown in Figure 1.1 and the timetable for individual research components in Table 1.4. A log-frame in Appendix 6 shows the positioning of this work in the context of a larger research project (DFID R7064) which also included sites in Karnataka State, India.

Field work progressively resolved from a regional, to district, watershed / cascade and finally community and household level over four years from 1999 to 2002 The process began with a detailed screening process (section 1.6.1) to determine fieldwork locations followed by a situation appraisal of two STCs using rapid participatory techniques. A concurrent situation analysis dealt with the national context, including trends in fish production, consumption and marketing, the administrative, political and economic situation. An in depth analysis of this phase of research is presented in a series of five working papers (Murray and Little 2000a – 2000d) and summarised at relevant points in this thesis including section 1.5 and Chaper 4.

Results of these activities together with outcomes of stakeholder workshops were used to formulate a participatory research agenda for the next phase of action research based on low input stocking enhancements. Results from these ‘phase 1’ pilot trials (2000) guided the design of a second phase (2000-2001). Phase 1 trials incorporated five tanks belonging to three communities and phase 2, six tanks belonging to five communities. Hatchery sourced tilapias which were stocked in phase 1 were replaced by a range of locally source seed in phase 2. Phase 1 trials were assessed mainly on the outcome of intensive collective harvesting events while a much more extensive range of participant and researcher managed techniques were employed to assess the staggered harvesting outcomes emphasised in phase 2. This phase was preceded by a detailed baseline PRA including wealth ranking used as the basis for the stratification of subsequent surveys including: daily fish yield monitoring, test fishing, adaptive learning based on regular feedback workshops, a fortnightly household livelihood monitoring survey, an irrigation management survey and finally, a participatory impact monitoring (PIM) survey.

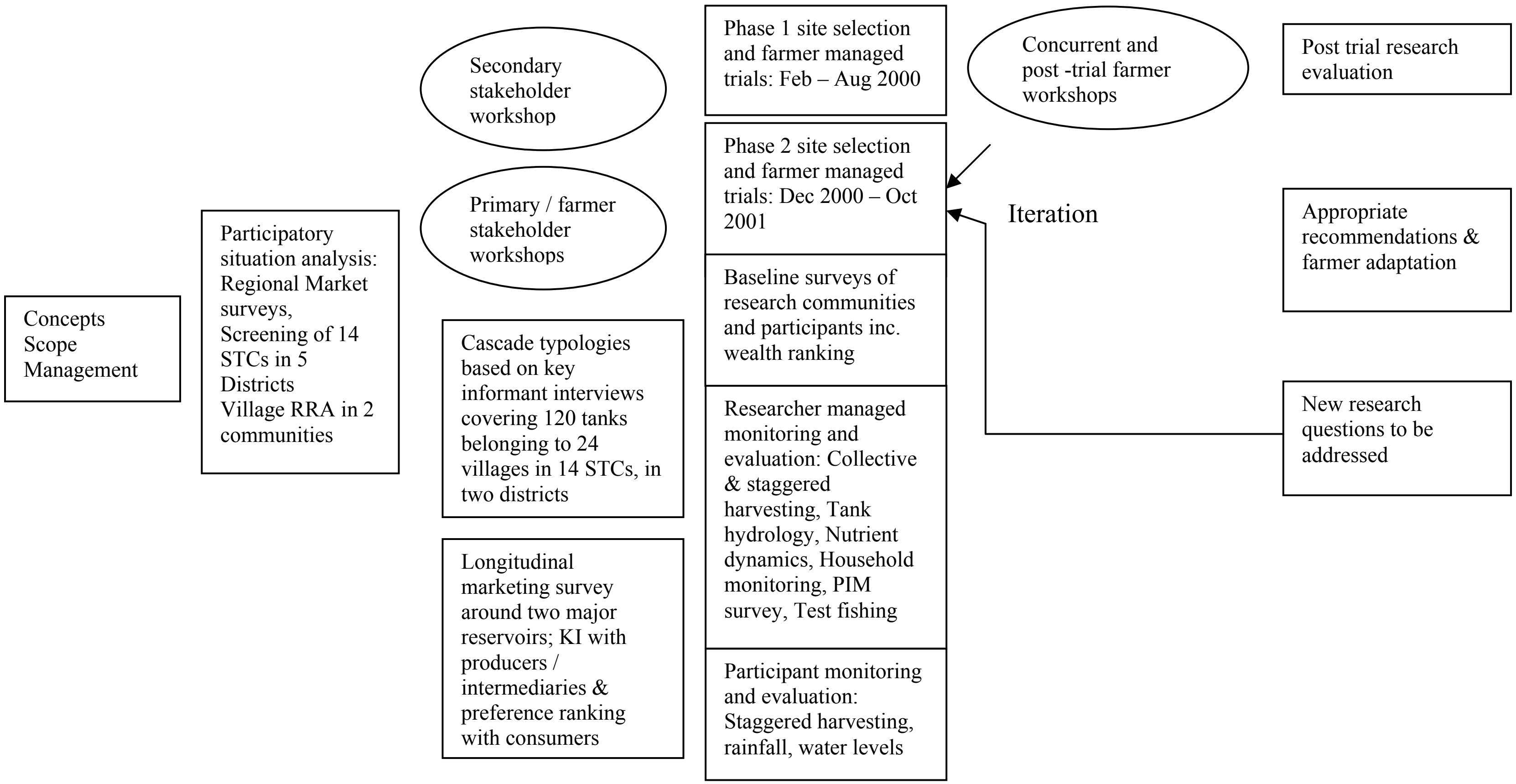
Two other longitudinal surveys; a tank topographic / hydrological survey and a water quality / nutrient dynamic survey were also carried out concurrently with the phase 2 trials. The main purpose of these components was to assess how the hydrology of the each of the intervention tanks influenced fish yield outcomes through its influence on seasonal nutrient and aquatic macrophyte occlusion profiles and fishing efficiency.

Over the course of both phases of action research, detailed ‘cascade typologies’ were also compiled in 14 cascades consisting of 120 tanks belonging to 24 village communities. Separate surveys focused on demography, land and livestock holdings, tank hydrology, *maha* 99/00 and *yala* 2000 cultivation patterns and *yala* 2001 spill events. Results are presented in Chapter 2.

Results of the marketing, hydrology and nutrient dynamics surveys are reported in two separate papers; Murray (2004a) and Murray (2004b). Once again, results are summarised at appropriate points in the text.

A detailed description of methodologies used to gather social information in the action-research villages is given in Chapter 3. Methods used in the watershed level hydrological survey are described at the start of Chapter 2.

Figure 1.1 The research framework



Stage 1: Scope of project, Preparatory work	**Stage 2:** Selection of research area and partners, participatory situation appraisal	**Stage 3:** Stakeholder workshops, identification of constraints, identification of farmer researchers & hypotheses, longitudinal situation appraisal	**Stage 4:** Action research incorporating community-managed trials, tank topographic and hydrological survey, water quality survey	**Stage 5:** Adaptive learning	**Stage 6:** Post-trial farmer workshop Information dissemination Cycle of continuing research
1998	**Jan 1999 – Jan 2000**	**Dec 1998 – Dec 2001**	**Jan 2001 – Jan 2002**	**Apr 2001 – Dec 2001**	**Jan 2002**

Year	1998	1999				2000				2001				2002	Chapters
Quarter	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	
1. Situation analysis & site screening															
Secondary stakeholder workshop	x														3,5
Secondary data collection	x	x	x	x	x	x									1,2,4,5,6
Screening of 14 STCs		x	x												1
Regional market survey		x	x												1
RRA in 2 villages *			x												2
Primary stakeholder workshops				x	x										3,5
Cascade typologies					x	x	x	x	x	x	x	x			2
Local market / consumer surveys				x	x	x	x	x	x	x	x	x	x		6
2. Phase 1 interventions															
Phase 1 stocking: 3 villages, 5 tanks						x									5
Phase 1 harvest								x							5
3. Phase 2 interventions															
Baseline surveys/ wealth ranking								x							3,4
Phase 2 stocking: 4 villages, 5 tanks									x	x					5
Phase 2 harvest											x	x	x		5,6
Topographic/ hydrological survey							x	x	x	x	x	x	x	x	2
Nutrient/ water quality survey							x	x	x	x	x	x	x	x	5,6,7
Longitudinal household survey									x	x	x	x	x		4,6
Test fishing										x	x	x	x		5
Staggered harvesting surveys											x	x	x		5
Adaptive learning workshops											x	x	x		6
Cultivation strategies survey												x	x		4
PIM survey													x		6
4 Post trial workshops														x	

* Danduwellawe & Pahala Diulwewa cascade systems, Kurunegala District, NWP.

Table 1.4 The research timetable 1998-2002

1.6.1 Screening and selection of field research areas

A range of secondary and primary information relating to poverty and natural resource characteristics were used to screen potential research areas. Additional criteria included potential institutional entry points, logistical and safety factors.

The DL1 agro-ecological zone (section 1.5) was selected as the wider research area because of its extensive coverage of the lowland Dry-Zone (Figure 1.2). The area also has the following general characteristics which are compatible with the project focus:

- Low and erratic water availability with heavy dependence on traditional rainfed tank irrigation-based crop production.
- Predominance of small-scale seasonal crop production and marked seasonality in food availability, income and employment opportunities.
- High levels of rural poverty as evidenced by high and rising levels of chronic protein malnutrition.

Within this area districts within conflict zones to the North and East were excluded, and areas to the south for logistical reasons.

Even in rural areas poverty is not a localised phenomenon, instead superimposed on wider trends; pockets of extreme poverty can be found through out the country. Screening therefore necessitated data collection at a range of progressively disaggregated levels. Secondary data from NGO's, Governmental and academic agencies on water availability (Chapter 2) and poverty indicators were collected at provincial and district levels (Appendix 3 and Appendix 4). Four districts which held the highest concentrations of small-tank resources, Puttalam and Kurunegala in North Western Province (NWP) and Matale and Anuradhapura in North Central Province (NCP) were subsequently selected for detailed screening at the field level. The poorest communities in these areas were identified using stunting, wasting and infant mortality data collected from local government medical officers (Appendix 5). This information proved much more reliable than other welfare indicators collected from Divisional Secretariats (DS) at a similar disaggregate level. Based on this information seven DS were selected for the next phase of cascade screening. This was a rapid process based on site visits, mapping exercises and key informant interviews. A total of 14 STCs over a range of terrain were evaluated using the method (Appendix 7 and Appendix 8).

Two of these systems incorporating a total of 21 tanks and 9 villages were selected for a detailed participatory livelihood analysis (Appendix 9). These and adjacent watersheds in two clusters located some 30km apart in Anamaduwa DS of Puttalam District and Giribawa DS of Kurunegala District, subsequently became sites for the first phase of action research (Figure 1.2). Site selection was also influenced by the presence of two NGOs, CARE International and IFAD, implementing integrated rural development programmes incorporating tank stocking with local communities. The intention was to foster collaborative partnerships while simultaneously building dissemination pathways into our research. However inter-community conflicts generated by poorly conceived fisheries interventions (Murray and Little 2000b) made some of these villages untenable as sites for action research. The same interventions also generated unrealistically high expectations which made lower input, but potentially more sustainable options, less attractive to villagers.

Next, primary stakeholder workshops were held in ten communities identified as candidates for action research in the two research areas. In these meetings research ideas were reviewed and needs assessments carried out.

The second intervention phase was restricted to the 'Giribawa' research area. Focus shifted to nine adjacent watersheds which straddled the Puttalam and Kurunegala District administrative boundary to the north of NWP. These included 'Ihala Maradankadawala' another of the cascades in the original rapid screening exercise. The selection of adjacent watersheds enhanced understanding of inter-community relational aspects in the management of tank resources, while greatly simplifying the operation of multiple longitudinal research components. These included the cascade typological surveys which initially continued in three cascades in the Anamaduwa research area during the phase 1 trials.

Prior to the onset of phase 1 trials a field research station incorporating a water quality laboratory was established near Galgamuwa a small town located between the two main research areas. This also serviced a linked DFID project (R7123) working in large scale reservoirs of the Mahaweli H system to the north (Appendix 8). This proximity facilitated the investigation of potential synergies between communities managing large and small-scale irrigation systems.

Galgamuwa was also a retail and wholesale point for the two most important commercial fisheries serving the Giribawa area. These were located in nearby Rajangane and Usgala Seyambalangamuwa Reservoirs (Appendix 1). Volume and price data collected from intermediaries in Galgamuwa were used to assess seasonal production from these two systems during the action-research phases, while consumer preferences were assessed within each of the phase 2 action-research villages.

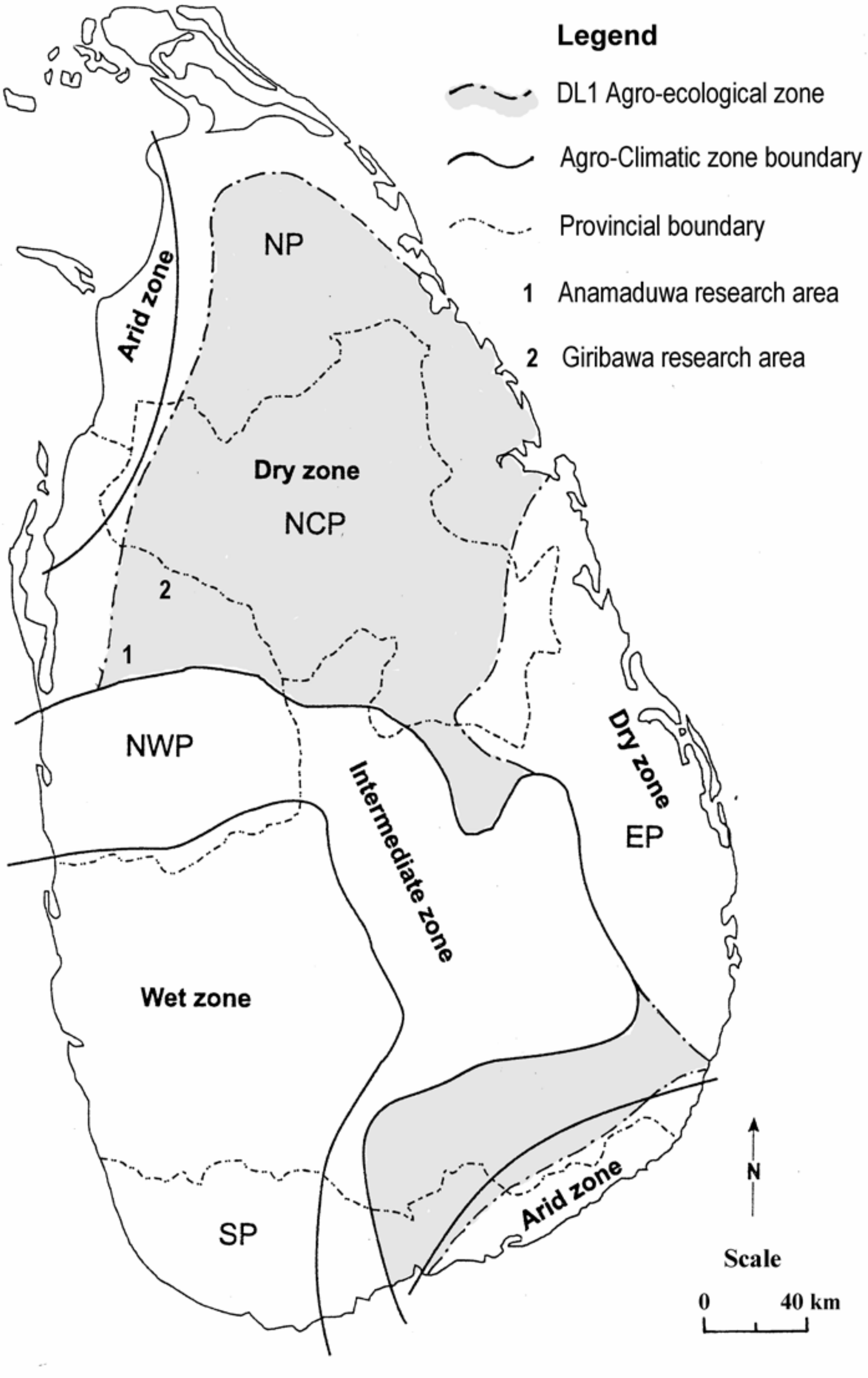


Figure 1.2 Location of principle research areas within the DL1 Agro-ecological zone of Sri Lanka

1.6.2 Outline of the thesis

Following is a brief summary of the contents of the remaining thesis chapters:

Chapter 2 provides a description of Dry-Zone watershed hydrological characteristics based on existing literature and results of key informant surveys in the research area. Simple classifications based on tank seasonality, spill-frequencies and spatial characteristics are used to assess the aquatic production potential of small tank cascades. Impediments to fish migration, including de-silting activities and surplus weir design, are also assessed. These combined results are used to evaluate the likely status of fish stocks in Giribawa watersheds prior to implementation of phase 2 action-research trials. The chapter commences with an assessment of the priorities of different water-user groups and potentials for conflict between them.

Chapter 3 provides a description of the methods and approaches used to gain understanding of the social characteristics of intervention communities. These included participatory methods, action research and adaptive learning techniques which are critically assessed. Details of the stakeholder analysis techniques are given following a description of the baseline and multiple impact monitoring surveys. A detailed assessment of participatory ranking / scoring techniques and their statistical treatment is also presented. These techniques were used repeatedly during different phases of the study. Finally the relational data management system used to deal with the complex and over lapping multi-disciplinary components of the study is described.

Chapter 4 provides a socio-historical description of the action-research villages. A literature survey is followed by analysis of a longitudinal livelihood survey in phase 2 villages. Poverty characteristics are assessed and the basis for social organisation around caste and kinship is described. Particular attention is given to assessing local institutional capacity in order to establish which organisations are best equipped to manage collective fishery enhancements. Farming systems are also described.

Chapter 5 commences with an outline of fisheries management options based on (1) a description of the traditional collective management practices (2) results of a baseline survey undertaken in a sample of tanks with different seasonal characteristics

(3) results of primary and secondary stakeholder workshops. Based on these findings and trial iteration, research hypotheses based on low input enhancements using hatchery produced (phase 1) and locally sourced fish stocks (phase 2) are described. In the second section results of phase 1 and 2 stocking enhancements are described and assessed. Biological indicators (survival, yield, growth and fishing efficiency) and simple cost benefit analyses are used to assess intensive collective fishing outcomes in phase 1 and 2 and staggered harvesting in phase 2. Results are validated against researcher managed monthly test fishing outcomes. Management strategies are also evaluated in terms of reciprocal participation between neighbouring communities.

Chapter 6 In this chapter, results of a fortnightly wealth stratified livelihood survey are used to compare the contribution of fish from stocking interventions to other sources of production at the household and intra-household levels in four phase 2 villages. The same structured survey is also used to assess the nature and level of conflicts associated with the multiple-use of tank water during the trial period. Yield estimates derived from this survey are compared with those described in Chapter 6. Also described, are the results of a second participatory impact monitoring (PIM) survey which compared farmer defined indicators before and after trials as well as overall farmer satisfaction. Participants were also asked whether they were willing to repeat the interventions and how they might be improved.

Chapter 7 Summary and conclusions of the study

Chapter 2 Small tank cascade and multiple water-use characteristics

2.1 Introduction

Water scarcity is the single most important constraint to agricultural livelihoods in rainfed areas of the Dry-Zone (Chapter 4: section 4.3.1.4). Consequently, the watershed appeared to be the most appropriate physical boundary in terms of our farming systems approach. The principle purpose of this Chapter is to assess the hydrological and related natural aquatic production characteristics of village tanks at the cascade level prior to the design of any stock enhancement measures. A secondary purpose was to comment on the wide divergence in opinion on estimates of the extent of the tank resource base, based on a comparison of secondary data with an accurate survey of watersheds in two research areas. The chapter begins with a brief summary of the background literature relating to the physical characteristics of small tank cascades. Next, the methods employed in our own survey are discussed, followed by results, discussion and summary sections. An assessment of the multiple-use characteristics of village tanks is also presented early on in the chapter, in order to provide important context at this stage of the thesis.

Kariyaswaram, Jayanande *et al.* (1984), Madduma Bandara (1985) and Tennekoon (1986) were amongst the first to emphasise the treatment of the whole cascade rather than individual tanks as the focus of study. Itakura and Abernethy (1993) conducted the first water balance study at the cascade level (Appendix 15). Most of these studies emphasised the cascade focus from an irrigation management perspective. Madduma Bandara (*ibid*) went further in recommending an integrated approach that considered both hydrological and social characteristics of the different communities accessing the cascade resource. Yet although there have been many notable studies by social scientists and geographers at the individual tank level (Farmer 1957, Leach 1961, Tennekoon 1974, Mosse 1997a: Chapter 4), no systematic integrated studies have yet been completed at the watershed level.

2.1.1 Village tanks

Most village tanks consist of catchment, drawdown or water-spread area, an earthen bund, one or more outlet structures (sluices) installed at different levels, one or more flood disposal structures (surplus weirs) and a system of unlined distribution canals serving the cultivated 'command area'. The shallow littoral area to the rear of the tank is often referred to as the foreshore. Full supply levels (FSL) are determined by the height of the (lowest) weir, which diverts surplus rainfall via a spillway channel or ephemeral stream bed to a lower tank or watercourse. In seasonal tanks residual pools persist longest in the deepest areas close to the bund. The elevation at the bottom of the (lowest) sluice is known as sill or dead storage level (DSL) and the area contained at this level is the dead storage area. Even the largest perennial tanks in the Dry-Zone rarely average more than 5-8m in depth over 75% of their area. Most tanks are no more 2-3m deep at FSL and considerably shallower over much of their parabolic profile.

Maximum water-spread (MWS) at FSL ranges from <2ha - 40ha in over 95% of cases (DAS 1997). In the research area, tanks receive most water during the Northeast Monsoon (Oct – Jan). The main *maha* cultivation season then lasts from Oct-Mar. Water levels recede from Feb-Mar onwards, but fluctuate due to intermittent rains during the SW monsoon (Apr-Jun). If these rains are sufficient there may be a secondary *yala* cultivation season between April and July. Water is used mainly for paddy irrigation during the *maha* season, while a range of other field crops (OFCs) are occasionally grown during the *yala* season. Shifting or fixed upland cultivation in catchment areas and home-gardening are other important components of farming systems (Chapter 4). Secondary uses of tank water include bathing and domestic purposes, livestock watering / pasture and subsistence fishing (section 2.3.1).

As a consequence of the shallow and porous soils over much of the Dry-Zone, percolation and evaporative losses are high (Appendix 15). Most tanks will fill (i.e. reach MWS) only after periods of intensive precipitation in above average rainfall years. Under non-system tanks which lack assured water supplies from trans-basin diversions, crop requirements are satisfied using a variable combination of stored water and direct rainfall. This is known as supplementary irrigation. Under progressively smaller seasonal tanks in upper watersheds, the application of stored water becomes increasingly periodic, particularly during drought years when farmers may be compelled to conserve limited supplies for use over the dry season. This is one reason why average crop yields under such systems are substantially lower than under perennial systems (MIWM 2003). The accumulation of more productive and water retentive low humic gleys in lower-watershed areas i.e. compared to the thin, porous red soils in upper-watershed areas, is the other main reason for this difference. Seasonal tanks are also more likely to be pumped down for emergency irrigation with adverse consequences for the maintenance of fish stocks and other aquatic organisms.

Historic evidence shows an awareness of the need for good watershed management for rice production and other uses, at least at the village level. Watersheds were divided into different sections identified for specific purposes; people had their houses and home-gardens close to the tanks, land adjoining the village was used for slash and burn (*chena*) cultivation, while forests in the catchment immediately above the village tank were left relatively undisturbed to minimise soil erosion and tank siltation (Ulluwishewa 1991). Traditionally, a pool receiving drainage waters was maintained at the lowest point of the paddy tract for use as a buffalo wallow. This was often a permanent body of water and acted as a refuge for fish which re-colonised other parts of the system during the rains (Ulluwishewa 1995). Farm mechanisation and increasing pressure on land has resulted in the loss of these wallows from many systems.

Most villages have access to one or more 'axial' and a larger number of smaller 'radial' tanks (Figure 2.1). Tennekoon (1995) observes that in the past, some of the smaller tanks would be designated as *olagama* for ground water stabilisation or *godawala* as water holes for village cattle and wild animals. Today there is permanent settlement around all but the smallest tanks and such demarcation is less evident. The same population pressure has also lead to increasing encroachment of catchment areas, especially in lower-watershed areas.

Each tank has its own immediate 'net' or micro-catchment area, but may also receive drainage returns and over-spill from tanks higher in the meso-catchment. The entire combined catchment of any tank, i.e. including any superior tanks, is known as its gross catchment area (Ponrajah 1994, Table 2.1). Smaller 'radial' tanks on the watershed periphery rely entirely on their own micro-catchments, while 'axial' tanks also incorporate additional tank(s) in their gross catchment. Understanding the water regime of any axial tank therefore requires an appreciation of hydrology and water management practices at the wider cascade level.

2.1.2 Small tank cascade systems

In the Wet-Zone, village tanks are supplied by perennial stream diversions (anicuts) whilst in the Dry-Zone they are typically rainfed via ephemeral streams and clustered into small tank cascades (STC - Figure 2.1, Plate 2.1). Madduma Bandara (1985), who coined the term, defined an STC as a series of hydraulically connected small tanks within a *meso*-catchment draining to a common reference point thereby defining a sub-watershed unit with a definite watershed boundary. The system stores, conveys and utilises water from first or second order ephemeral streams (Madduma Bandara *ibid*), i.e. most cascades are located in first or second order inland valleys. A cluster of cascades would in turn form a sub-basin of a river, with a cluster of sub-basins forming the entire watershed of the river. There is no flow in the ephemeral streams from February to October except for the first order streams, which may be briefly re-activated during the March to April rains.

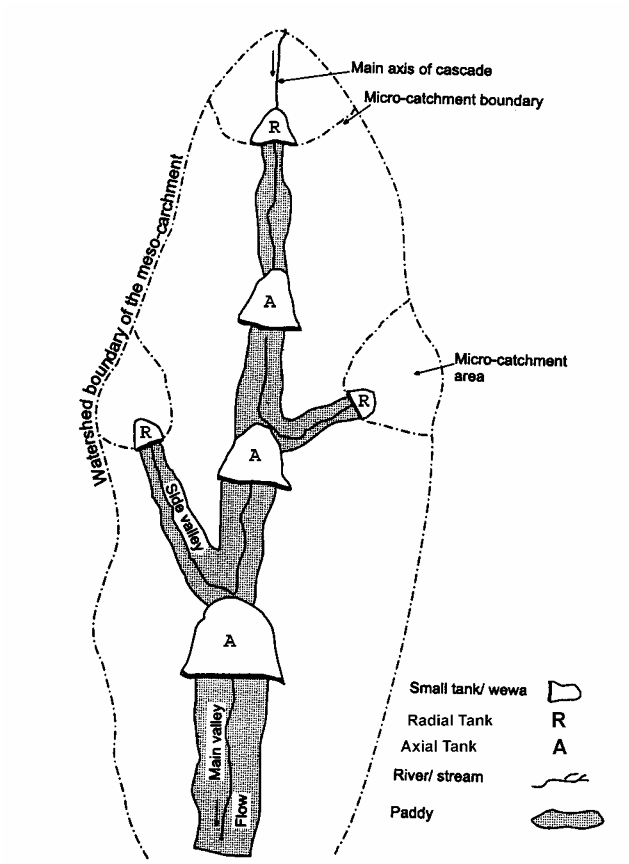


Figure 2.1 Schematic plan of a simple linear small tank cascade system (modified from Pannabokke, Sakthivadivel *et al.* 2002)

STCs investigated in the current study were comprised of 3 - 34 tanks, with from 2 - 19 tanks per village. Tanks are arranged in linear or, where there are side-valleys of the main axis, more branched radial patterns. Tank size generally increases with progression down the main axis of the watershed.

Plate 2.1 Arial view of a small linear cascade system, consisting of four tanks. Taken from the summit of an inselberg at the head of the watershed; Mihintale, North Central Province, June 2000

2.1.3 Distribution patterns

There are estimated to be 3,500 to 4,000 STCs in the country with greatest concentrations in the selected project areas of the North West and North Central Provinces. Tank density averages one tank per 2.6 km^2 of Northern, North Central and Southern Provinces and one tank per 1.2 km^2 of North Western Province (NWP). Sakthivadivel (*ibid*) identifies three principle factors governing the distribution patterns and densities of STC systems:

- *Rainfall distribution & amount:* Density decreases with increasing rainfall
- *Nature of the underlying geology:* Soil permeability; typically lowest in upper watersheds, influences tank size, distribution and seasonality.
- *Geomorphology:* Density is greatest in the 'gently undulating' areas (2-4% slope range) due to the greater retentiveness of the water table and lowest in the 'undulating' areas (4-8% slope range).

Because of these factors, most STCs are concentrated around the larger rivers and their tributaries. There are 102 river basins in the Dry-Zone. In Anuradhapura District (the largest district in Sri Lanka), a comparatively high density is found over a central belt of Precambrian rocks, which give rise to a more compact and impermeable soil catena than in the SW of the district.

Estimates of the total number of tanks vary widely between sources (section 2.3.3.3). However, it seems safe to conclude that there are at least 18,000 in various states of repair. The distribution of 'known' tanks is summarised in Figure 2.2.

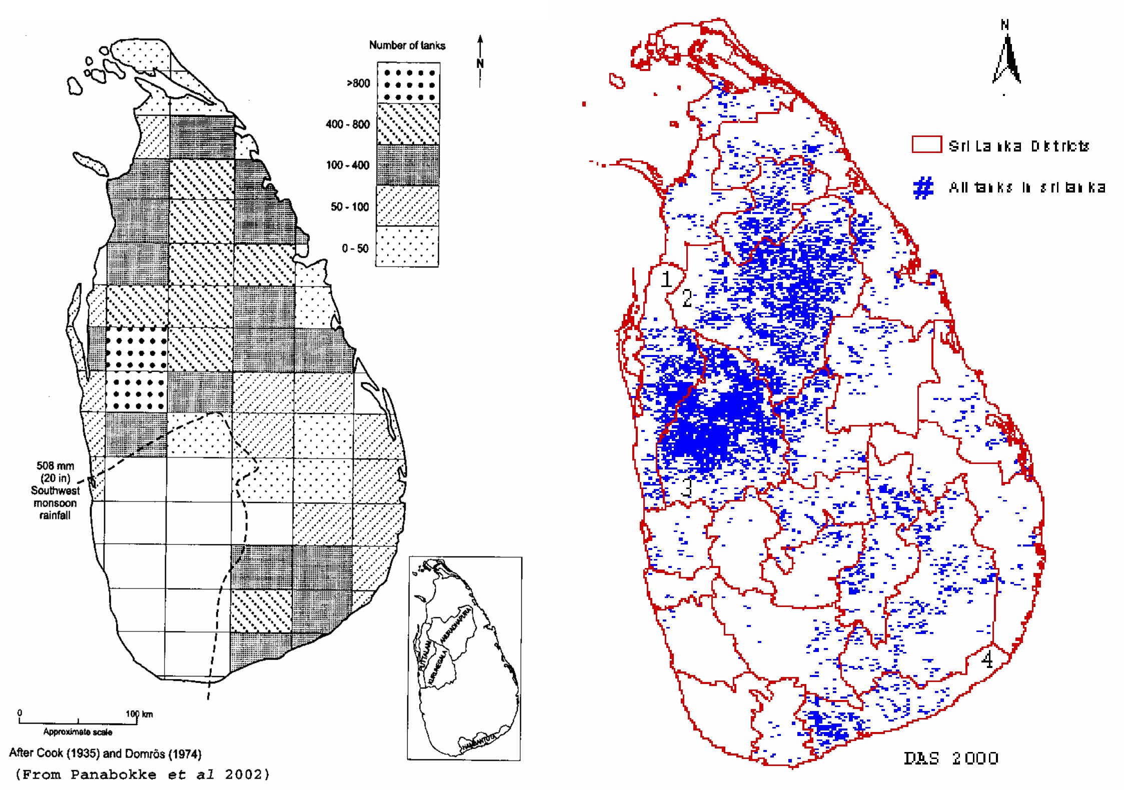


Figure 2.2 Island-wide distribution of tanks showing high densities in Puttalam (1), Anuradhapura (2), Kurunegala (3) and Hambantota (4) districts.

2.1.4 Cascade hydrology

In this Chapter, we are principally concerned with cascade hydrology. The hydrological endowment of an STC is affected by the spatial and temporal distribution of rainfall, surface and groundwater potentials (Sakthivadivel *et al*. 1997). Tennekoon (1986) suggests that the importance of cascade level hydrological linkages were well understood by early settlers. This is reflected in the following planning principles "applied by farmers during tank construction": (1) allowing an adequate volume of water in every tank in the settled village, even during years of below average rainfall (2) instituting a regulated downstream flow of water to minimise the risk of bund breaching (3) set-aside of surplus storage for ground-water recharge.

These observations imply that there was an implicit understanding that altering the hydrology of one or a few tanks could alter the surface and ground water hydrology of the whole cascade. However, Sakthivadivel (pers. comm.) suggests that lower population levels in the past, meant that a more trial and error approach was acceptable. Consequently, most tank cascades came into existence over extended periods. Furthermore, social factors often took precedence over hydrological factors. As a result, it is common to find incompatibility between tank, catchment and command area. Sparse settlement also meant there were likely to be fewer different kinship groups (Chapter 4) within each cascade system; perhaps increasing the likelihood of coordinated development. Tanks would also have regularly have fallen in and out of repair or been abandoned entirely due to the depredations of disease and conflict. Only today are watersheds progressively being harnessed to their maximum capacity as pressure on limited land and water resources increases. Therefore, it is likely that the consequences of uncoordinated tank rehabilitation will become an increasing problem.

Nevertheless, most institutional rehabilitation planning continues to be based on hydrological assessments at the individual tank rather than the cascade level. Routine assessment is based on available meteorological data, topography, geology and limited hydrological measurements, but with no assessment of the potential of surface water or ground water recharge. There has been no systematic attempt to collect and organise hydrological data for any portion of Sri Lanka's Dry-Zone. Poor understanding and inadequate data have probably contributed to the disappointing record of many small tank rehabilitation efforts in the past. The number of studies on small-tank hydrology to date is extremely limited (Sakthivadivel, Fernando *et al.* 1996). Some of their key findings are summarised in Appendix 15.

In order to gauge contemporary farmer attitudes to these issues, during our preliminary research, villagers were asked how they might improve the productivity of their irrigation systems. Responses consisted primarily of physical options: tank excavation (de-silting) or increasing bund height to increase tank capacity and installing pumps to increase drawdown potential. Most farmers interviewed did not think beyond the limits of their own tank(s) and generally had a poor perception of the consequences that their management or rehabilitation strategies might have on other downstream or upstream users within the same cascade. The potential for uncoordinated rehabilitation activities to move water-deficits downstream was much more poorly perceived, probably due to the reduced visibility of such impacts against the background of highly erratic seasonal water availability.

A close association of kinship, land tenure and irrigation practice traditionally provided the basis for community management of these assets. Today a variety of social, political and economic trends together with increasing pressure on land and water resources have contributed to the erosion of traditional catchment management practices. These aspects are discussed in Chapter 4.

2.2 Methodology

A rapid hydrological inventory of fourteen watersheds comprising 120 tanks was carried out between January 2000 and May 2001. Four of the watersheds were located in the Anamaduwa research area and ten in the Giribawa area. These consisted of a total of 25 and 95 tanks respectively. This information was used to asses the status of resident fish populations and natural production potentials prior to phase 2 stocking interventions. Information was also collected on the multiple-uses of village tanks held in common ownership.

Data collection combined direct observation, key informant interviews and a range of participatory rural appraisal methods (PRA: Chapter 3). Key informant information relating to seasonality and spill events was also complemented by detailed observational studies on a subset of 25 tanks covering a range of watershed locations in the Giribawa area between 2000 and 2001. These methods are described in the following sections. A glossary of terms and abbreviations used in this Chapter is given in Table 2.1.

Table 2.1 Glossary of hydrological terms relating to tanks

Term	Acronym	Description
Afflux		Level of temporary water level above FSL during flood episodes
Bund		Earthen embankment impounding water in a natural hollow
Catchment area	Ca	*Net Ca* immediate area draining into tank. *Gross Ca* total area draining into tank including net area of superior tanks
Catchment ratio	CaW	Ratio of catchment to maximum water-spread (MWS) area
Command ratio	CoW	Ratio of command area to MWS area
Command area	Co	Maximum irrigable extent of land below tank
Cropping intensity	CI	Ratio of irrigated to total cultivable area during the *maha* season, or over the entire year.
Cropping frequency	CF	Frequency of *maha* and *yala* cultivation over five years
Dead storage	DS	Body of water below DSL which is not available for gravity fed irrigation
Dead storage level / sill level	DSL	Water level at lowest point of sluice inlet
Form Index	FI	Ratio of cascade area to its overall length – a measure of shape ranging from linear to branched
Freeboard		Height of bund above HFL allowing for fetch & wave action
Full supply level	FSL	Water level at the top of the surplus weir
Gross Catchment area	GCA	Area of land draining into a tank including the catchment area of any superior tanks in the same watershed
High flood level	HFL	Maximum temporary afflux above FSL during extreme flood events
Live storage	LS	Storage contained between FSL and DSL and available for gravity fed irrigation
Maximum water-spread	MWS	Surface area of tank inundation at FSL
Net catchment / micro-watershed area	NCA	Area of land draining into a tank excluding the catchment area of any superior tanks in the same watershed.
Small tank cascade	STC	Hydraulically connected tanks draining to a common point
Spillway channel		Temporary water course diverting spill water to lower tanks
Surplus weir		Earthen or permanent structure controlling discharge of flood waters and regulating storage capacity

2.2.1 Water-use priorities

Before discussing results of the hydrological research components described above, findings from pilot PRA exercises regarding the multiple-use characteristics of village tanks are presented; their overall value to farmers in respect of their constituent engineered structures, physical substrates and stored water are assessed (Murray and Little 2000b). This is in order to provide context regarding the interaction and relative importance accorded to fisheries compared to other potentially competing uses. Farmers in two villages, Pahala Diulwewa (PDW: Anamaduwa, n = 28) and Danduwellawe (DDW: Giribawa, n =16), were asked to consider their most accessible tank, to identify the different ways in which they used this resource and finally, to rank the overall importance of the different uses.

First, key informant interviews were used to elicit the principle uses, which were common to both villages. Individuals were then asked to rank each of these criteria. In this instance a fixed scoring system was applied, i.e. respondents divided a fixed number of counters to the different criteria represented by images on cards. In order to assess the effects of wealth and gender, the sampling design included approximately equal numbers of randomly selected respondents from each of three wealth groups, while 37% of all respondents were female. Preference ranking and scoring techniques were also adapted and applied during other research components as described in Chapter 3. In this instance results were analysed using Friedman's test (Chapter 3). The main externalities and conflicts associated with fishing and its competing uses are also discussed in section 2.3.1.1.

2.2.2 Rainfall Data

In order to evaluate climatic trends, mean weekly rainfall data from1984-2001 was collected from local government offices (Department of Agrarian Services - DAS) in the two research areas. Mean monthly and annual distributions are presented in section 2.3.2. The 75% relative probability occurrence of rainfall is also calculated. This is the amount of rainfall that is likely to be achieved or exceeded in 75% of years, averaged over successive 30-year normal periods, i.e. the 75% inter-quartile value for data ranked in descending order. The measure is more conservative than the meteorological office mean rainfall values (which approximates to the median 50% relative probability rainfall in normally distributed data). Given erratic rainfall conditions, the 75% value is a more appropriate measure on which to base tank yield calculations and is used by the DAS for tank design and rehabilitation. As will be discussed in section 2.3.6, the choice of design criterion also has great significance for fish migration potentials and natural recruitment through its influence on spill frequency.

In addition to this secondary data, farmers around five of the tanks that subsequently became the focus of action research were supplied with rainfall gauges with which they recorded daily rainfall levels from April 2000 to February 2002. Two additional sites were located at Danduwellawe (DDW) and Galgamuwa town approximately 15 and 20 km from the research area respectively. The latter site was maintained by research staff, who were also responsible for monitoring daily minimum and maximum temperatures. Data from one site; Lokahettiyagama (LHG) was discarded due to poor record keeping. The locations of the recording sites are shown in Figure 2.6 and results discussed in section 2.3.2.

2.2.3 Watershed mapping and tank inventory

As a component of village PRA exercises (Chapter 3) groups of farmers were asked to name and map the position of as many tanks as they could recall in and around their villages. Farmers were also asked to mark spill linkages on their maps thereby assigning tanks to individual watersheds. Results were triangulated against 1:50,000 survey maps (GoSL Survey Dept.1988) and checked on the ground, using trail bikes to reach remoter areas. Locations of all tanks omitted from the survey maps were plotted using a GPS system (GARMIN Etrex). Next, based on contour information, drainage patterns and PRA results, watershed boundaries were plotted on the 1:50,000 maps.

Using this methodology, an inventory of all the tanks located in 14 watersheds in the two research areas was completed. Despite this exhaustive process, a number of small mostly private tanks in remote jungle continued to be ‘discovered’ during fieldwork over the next two years. These were retrospectively included in the survey. Discrepancies between our results and the OS survey were used to assess the validity of widely ranging estimates of the small tank resource in the Dry-Zone.

The inventories were also subsequently used to solicit a range of information regarding the social, physical, hydrological and cultivation history of the tanks from local key informants. Farmer estimates of maximum water-spread area (MWS – the maximum surface area of water obtained at full supply level (FSL), i.e. when the tank begins to spill) proved highly inconsistent, particularly for larger tanks. Results were therefore triangulated with planimetric area measurements from 1:50,000 survey maps. The method is described in Murray (2004b). The areas of tanks not included on the survey maps were based on the average of key informant estimates and / or cross-sectional GPS measurements during the dry season. GPS data was used to approximate bund length and bund to foreshore distances (accurate to ± 15m). Areas were then calculated using regression models derived from detailed topographical surveys of six of the tanks in the Giribawa area (Murray 2004b, Appendix 16 and Appendix 17).

2.2.4 Farmer recall of recent hydrological trends

Farmers were asked to recall the frequency, duration and timing of the following events over the previous five years (1) tank drying extent and duration, (2) *maha* and *yala* spill events (3) *maha* and *yala* cropping events.

The first question presented some difficulty as farmers often classified as 'dry', tanks which held insufficient water for gravity fed irrigation, yet still retained a residual amount of water in the dead storage area. This is consistent with farmer irrigation priorities, but clearly of little use for assessing aquatic productivity. Consequently, informants were asked to recall the number of occasions when, in their view, insufficient water remained over the dry season to allow survival of tilapia stocks prior to the next rains. Under this definition, some of the more durable air-breathers may have been able to persist in shallow muddy pools. However, tilapias were selected because they were most important in terms of yield and their loss indicated little likelihood of substantial production in the following season. Spill events were defined as events that lasted longer than a single day during any single cultivation season. As an aid to farmer recall farmers were asked to remember occasions when 'spill-fishing' took place. This is associated with the upstream migration of fish during spill events and is often undertaken as a collective activity (Chapter 5).

Experience showed that five years was the maximum period with which farmers could recall seasonality and spill events with reasonable accuracy. All data was triangulated by at least two key informants and assessed for logical consistency. Additional key informants were consulted where there were wide differences of opinion. The final data set incorporated the 5-year period inclusive of *maha* 1996 to *yala* 2001. During the final year, results were also triangulated with researcher observation. This included monitoring of the onset and duration of *yala* 2001 spill events in a sample of twenty-five tanks in the Giribawa area.

Key informants who participated in these exercises included executive members of local farmer organizations, retired village headmen and local government officers. The latter group include the *Grama Niladhari* whose duties include the inventory of various village assets and conflict mediation. GNs proved highly reliable, especially when they were resident in the village under question. An extremely detailed community map of Ihala Maradankadawala (IMK – an action-research village) drafted by the local GN is shown in Appendix 28: Fig A27.5. This includes 19 tanks belonging to the community.

2.2.5 Classification of small tank cascade systems based on their hydrological endowment

The method of Sakthivadivel *et al.* (1997) was employed to classify our cascades in terms of their overall hydrological endowment using the data described in the previous sections. The method was based on an assessment of 310 small tank cascades (STC) under similar agro-ecological and climatic conditions in neighbouring Anuradhapura District. It provides a rapid means for assessing hydrological endowment so that tank rehabilitation might be coordinated more effectively at the cascade rather than the usual village level. The implications for aquatic production are also discussed below.

The simplest part of the classification is based on a topographical assessment using 1:50,000 survey maps. First, the form of the cascade (linear or branched) and size class, based on the total area of the meso-catchment, is defined. Size classes range from small (<1,000ha), medium (1,000 to 2,000ha), large (2,000 to 3,000ha) to very large (>3,000ha). A form index is calculated from the overall area to length ratio. Further subdivision is based on the configuration of the main valley axis and side valleys. Given similar soil characteristics, water retention is greater where the slope of the axis is gently undulating (2-4% slope) than when it is moderately undulating (4-8%). Overall tank density within the cascade usually increases with the number of side valleys. This in turn tends to reduce the ratio of catchment to tank water-spread area. However, 'nodal' tanks at the confluence of branches tend to benefit from increased inflow. Thus, hydrologically better-endowed STCs tend to have a combination of a linear or slightly branched form (with a higher form index) and a gently sloping gradient of the main axis.

The second part of the classification is a more quantitative assessment of hydrological endowment. It is based on ratios of gross maximum water-spread (MWS) to catchment (CaW) and command area (CoW) as well as cropping intensity (CI - see below). CaW ratios below 7.5

indicate that there is little potential to harvest additional water by increasing tank capacity, while CoW ratios above 1 indicate that command areas are over extended.

Cropping intensity is a measure of the extent (cultivated area as a proportion of total command area) and frequency of cultivation calculated over a specified period. It is a particularly useful hydrological indicator; it integrates both physical and social criteria as CI outcomes result from a combination of bio-physical, economic and other management constraints. It is also easily measured using farmer recall. Unfortunately, only a partial dataset was collected for the tanks in this survey and therefore a more basic cropping frequency (CF) measure is applied; i.e. ignoring the extent of cultivation. For each cascade, the weighted average CF is presented for the 5-year period from 1996-2001. This is calculated for each of the *maha* and *yala* seasons. CI results are presented for seven of the tanks which were subsequently stocked in Appendix 16.

2.2.6 A typology of aquatic production potential

A typology of natural aquatic production potential in un-stocked tanks should include seasonality and spill frequency; hydrological characteristics; which limit dry season survival and fish migration potential respectively. Two rapid classification systems were produced; one based on tank watershed position from 1:50,000 survey maps and the other on farmer recall of spill and drying events. Results of the classification were correlated with tank size and outcomes compared between the two research areas. Seasonal nutrient profiles were also surveyed in order to extend this typology in terms of growth as well as survival potentials. Methods are given in Murray (2004b) and results referred to in Chapters 5 and 7.

2.2.7 Baseline watershed assessment of resident fish populations

The main purpose of this research component was to assess the baseline status of natural fish populations in the Giribawa watersheds prior to implementing the second of two phases of stocking trials (Chapters 1 and 7). Depletion of stocks in more seasonal tanks over a succession of drought years, allowed a relatively accurate assessment based on dry season survival and subsequent upstream migration potentials supplemented with test fishing. Seasonality and spill information was solicited from key informants and by direct observation in a sample of 25 tanks in upper to lower-watershed positions. Spill events were monitored during the *maha* 99/00 and *yala* 00 seasons while hand and cast nets were used to assess fish survival in residual storage between August and September 2000. The extent of residual storage was also recorded.

Similarly, test netting combined with observation of local fishing activity was used to assess the migration activity of fish in the spillway areas immediately below surplus weirs when the tanks were spilling. Key informant information on seasonality and spill events for most of the remaining tanks in the Giribawa watersheds increased the sample size to 91 tanks. At the same time, an inventory of surplus weir characteristics was compiled for all the survey tanks in the Giribawa area (n = 95) in order to assess the degree to which different structures impeded migration. Survey information included construction material, height, length and down stream slope of weir and presence of lower anti-scour structures.

2.3 Results

2.3.1 Farmer priorities for use of water resources in village tanks

Similar criteria were identified in both pilot villages, PDW and DDW. These included: irrigation, bathing, domestic uses (clothes washing in the tank and *ex-situ* toilet purposes), livestock watering, fishing and a range of micro-industrial uses, e.g. brick making, cadjan thatch retting and pottery making. Some of these uses related directly to the water and some to the physical fabric of the tanks, e.g. brick making and livestock grazing.

Friedman's test revealed significant concurrence between farmers regarding the importance of various uses (Appendix 10). Irrigation and bathing ranked significantly higher than other uses ($P < 0.05$) in both villages. The surprisingly high placement of bathing above other productive uses was due to several factors. Firstly, increasing reliance on off-farm labour and decreasing productivity of land linked to land fragmentation, decreasing soil fertility etc. has reduced the relative importance of irrigated crop production to many households. This trend is more marked under the most seasonal tanks where irrigation becomes increasingly supplementary. Bathing, by contrast, remains an important daily social event within the local culture regardless of social status. Even off-farm workers are likely to congregate around the tank in the evening to meet friends and exchange news while bathing. Landless villagers were likely to rank bathing as their highest priority.

Only livestock watering was ranked significantly higher than any other uses in PDW. This reflects higher pasture availability and correspondingly higher livestock holdings in the Anamaduwa area. There was no significant concurrence regarding the order of other uses, which nevertheless, will be described in order of their overall median ranking. Many farmers valued the ancillary use of water and clay excavated from tank beds for brick production. In addition to small-scale commercial production, many households produce bricks to construct their own 'permanent' family house, for which they will assemble materials as funds and time allow. This ambition is the main legacy of the *Gam Udava* 'village awakening' policy of a populist government during the late 1980's, which prioritised the construction of a million new homes (see Chapters 3 and 4).

Fish production achieved a lower and middle level median rank in PDW and DDW respectively. This low overall priority is probably due to the availability of low cost commercial substitutes to fish production in village tanks (Murray 2004a), while the relative difference may be a result of higher-caste and wealth status in PDW village. Negative perceptions towards subsistence may also have influenced the results of poorer households who were subsequently found to be more dependent on subsistence fishing (Chapter 6).

None of these villagers reported using tank water for their own consumption; all the villages surveyed had access to at least one hand well and / or agro-well. However, a small number of poorer households in Galenbindunewewa, a village which had problems with saline ground water, were later found to collect water from the foreshore of their main village tank for cooking and drinking (Chapter 4). This was a perennial tank in a remote, sparsely populated area and consumption was restricted to a period of 2-3 months post inundation while the tank was relatively full and the water clear. Similarly a few households around Medibegama, one of the remoter radial tanks belonging to Gurulupitigama village also consumed tank water. In this case the (small) tank was rarely visited by other villagers. A more common practice with adverse health implications was the tendency of farmers to collect pooled irrigation water to slake their thirst while working in paddy fields.

A wide range of other tank functions were identified during subsequent phases of research. These are also shown in Table 2.2 with corresponding pictures of many of the uses in Plates 2.2 A-M. With the exception of human consumption, hunting and enhanced social status, these uses refer to more communal rather than more tangible and immediate household or individual benefits, e.g. ground water recharge, flood prevention, environmental amenity and symbolic capital. Their omission reflects understandable self-interest but also limitations of the rapid PRA techniques employed.

A further limitation was that farmers were asked to focus on a particular tank when in practice some uses are demarcated to different tanks. This is particularly the case in larger villages such as IMK with multiple resources. Priorities for some uses also show a marked seasonal or annual variation that was not reflected in the analysis. For example, irrigation was evidently not a priority during a succession of low rainfall years when the command areas of many tanks remained uncultivated (section 2.3.3). Conversely, bathing is a consistently important on a daily basis throughout the year. From a development perspective, understanding of farmer priorities is most important when there is a requirement for trade-offs because of negative externalities which alternative uses impose on each other. Negative externalities are likely to become most acute in seasonal tanks as discussed in the next section.

Table 2.2 Multiple-use functions of village tanks and potential negative externalities associated with different uses (asterisked functions – listed in decreasing order of priority -were identified by farmers during preliminary RRA and other functions during longer-term research)

Resource use	Benefits and **[negative externalities]**
Irrigation and drainage	
- Irrigation*	- Distribution to command area **[principle consumptive use]**
- Groundwater recharge	- Dry season cash crops under agro and tube wells below bund, perennial cropping in adjacent home-garden areas
- Silt harvesting	- Trapped silt formally used as field fertiliser **[Percolation losses]**
- Flood protection	- Reduces soil erosion, protects physical infrastructure below tank
Domestic uses	
-Bathing / washing clothes*	- *In-situ* tank use **[quality modifier, soapy off-flavours on fish]**
- Toilet, dish washing*	- *Ex-situ* domestic use
- Drinking	- Consumption of groundwater by most people and tank / surface water by a few poorer villagers and farmers working in fields.
- Vehicle washing	- Bikes, vans, tractors washed *in-situ* **[water quality modifier]**
Livestock	
- Watering*	- Year round along the foreshore **[water quality modifier]**
- Grazing*	- Tank bed in rainy and dry seasons, command area in dry season - Manure nutrients enhance primary productivity and fish growth
Biomass gathering	
- Fisheries*	- **[Water quality modifier, percolation losses]**
- Wild game	- Hides and traps positioned around residual water in the dry season
- Aquatic plants	- Macrophytes in littoral areas **[+/-trophic status and productivity, accelerated silting, navigation, bathing, fishing impediment]** - Provision of human foodstuffs (i.e. lotus tubers, 'green leaves' etc) and livestock fodder
Micro-industries	
- Brick / pottery making*	- Excavation of clay / kilns around tank bed[1] **[quality modifier]**
- Cadjan retting*	- Soaking of palm leaves for roofing etc. **[water quality modifier]**
- Construction*	- Water, sand and gravel extraction **[increased percolation losses]**
- Illicit distilling	- Stills located in immediate catchment[1] **[water quality modifier]**
- Tank bed cultivation	- In fertile draw-down areas **[increased percolation losses]**
Environmental amenity	
- Habitat	- Direct and indirect provision of habitats for a wide range aquatic terrestrial, and avian fauna **[predation on fish stocks]** - Maintenance of biodiversity
Physical benefits	
- Roads	- Built across bunds **[stronger bunds and regular maintenance]**
- Steps	- Bund steps facilitate access to deep water areas
Social benefits	
Ceremonial	- Pre and post-harvest ceremonies by bund to propitiate village gods
Status	- Position in social hierarchies re-enforced by ceremonial or regulatory roles **[relative marginalisation of landless villagers]**

[1] Location determined by proximity to water and fuel wood resources in adjacent catchments.

Plates 2.2A-M Some multiple uses of village tanks in the Giribawa research area. From left to right to – Row 1: A) Harvesting irrigated rice, B) bathing, C) washing clothes, - Row 2: D) Washing a tractor, E) Water buffalo wallowing, F) Cutting reeds for mat weaving, – Row 3: G) Line fishing, H) Brick-making, I) Weaving retted cadjan, - Row 4: J) Washing wild 'green leaves' food crop, K) Distilling illicit *kassipu,* L) Propitiating village gods with a *Kiribaht* (milk rice)ceremony after harvest, M) personal hygiene!

2.3.1.1 Multiple water-use, externalities and conflicts

Externalities are costs (or benefits) of economic activity (productive or consumptive), which are also borne by those not directly benefiting from the activity and therefore not fully reflected in its pricing (Bishop 2001). The likelihood of negative externalities is greatest for 'non-excludable' public goods, a category that includes common pool resources such as village tanks (Chapter 1). In this case negative externalities arise mainly as the result of tank or water uses that reduce the availability or modify the quality of water (Table 2.2).

These externalities may require trade-offs between competing uses in order to mitigate conflicts. Pearce (1993) and Randall (1991) devised a 'total economic valuation' methodology (TEV) as one means of addressing this problem. Although this compares the value of water for the range of goods and services it yields, placing an economic value on uses which range from productive to non-productive and from tangible to symbolic is extremely problematic. Renwick (2001) used the technique in Kirindi Oya, a major reservoir in the southern Sri Lanka and found that commercial fisheries constituted approximately 18% of the net value of annual paddy production from 1989 to 1997. However, the perennial nature of the reservoir meant that there was little competition or negative externality arising from the two concurrent uses. Conversely, the likelihood of trade-offs is likely to become progressively more acute as tanks become smaller and more seasonal in upper-watershed areas; though at the same time, decision-making is simplified due to the involvement of fewer stakeholders. In these cases complex trade-offs correspond with overall priorities ascribed to different water uses (section 2.3.1). Outcomes will also depend on the relative size and influence of different user groups who express them and there are both economic and non-economic motives for individual priorities, i.e. such as preserving status. Although irrigation is of primary importance for landed villagers, bathing is a priority for all villagers with few exceptions. Consequently, there is informal consensus on maintaining an adequate quality and quantity of water for bathing as long as possible into the dry season. This water might otherwise be pumped down for irrigation.

Conversely, with the exception of poorer households who rely on staggered harvesting for their subsistence, fishing is a low priority for many, (Chapter 6). As certain kinds of fishing can increase turbidity and farmers perceive that fishing increases percolation losses (Murray 2004b), it is normally subordinated to bathing and irrigation. Certain types of fishing gear will be informally restricted to proscribed seasonal windows (Chapter 5) and intense collective fishing episodes are promoted by influential villagers who would otherwise see little benefit from intermittent subsistence production. Deviations from these traditionally accepted norms can initiate major conflicts. Failure to acknowledge the externalities imposed by fish production has clearly contributed to the failure of stocking interventions in the past.

Bathing also has negative impacts on fishing as it can impart soapy / muddy off-flavours in fish during the dry season. Negative consumer perceptions regarding these off-flavours are signposted by the darker colour of seasonal tank tilapia, which, combined with their relatively small size compared to produce from larger tanks, results in a low commercial value (Murray 2004a). Evidently, this is something fishers must accept. However, there are also important positive externalities for fishing from these and other uses. Maintenance of stored water for bathing also extends the growing period for fish production and reduces the likelihood of tanks drying with complete loss of stocks. Equally important, livestock grazing around the tank provide many of the nutrients that sustain high aquatic production potentials (Murray 2004b).

Stocking related conflicts are considered further in Chapter 6: section 6.2.1.2. In the following section rainfall trends in the two research areas are reviewed, after which the hydrological characteristics of the watersheds are assessed.

2.3.2 Rainfall characteristics and tank operational design calculations

The application of the DAS yield criteria described in section 2.2.2, means that averaged over a sufficiently long period, 100% cropping intensity should be achieved in 75% of years with sub-optimal yields and / or reduced cropping intensity in the remaining years. This is considered an acceptable ratio of risk to economic potential for prevailing conditions. The required reservoir capacity and irrigable extent depend not only on the total amount of rainfall and run-off, but also the distribution of rainfall over the *maha* (Oct – Mar) and *yala* (Apr-Sep) cultivation seasons. Yield calculations are therefore based on the 75% probability of monthly rainfall during the main *maha* rainfall assuming zero residual storage after the previous dry season.

While the use of relative probability data masks some the variability faced by farmers (i.e. no single year is likely to be characterized by all the 75% monthly probability values) the irrigation department report that in their experience this simple method gives acceptable results (Ponrajah 1994). It should be noted however that guidelines currently observed in use at field level utilize a normal period from 1964-84 which should be updated with more recent rainfall data. The use of the 75% value has great significance for fish production levels in 'seasonal' tanks, as it also implies that tanks can be expected to spill at least once in every four years over the same normal period. In other words on average, it may be 3-4 years before tanks that have completely dried are naturally repopulated by the migration of fish during spill events.

Because of high percolation and evaporation rates in upper-watershed areas, rainfall duration and intensity will be as critical as total rainfall levels in determining the frequency of spill events. However, it was difficult to estimate these variables as no suitably disaggregated secondary data were available (only weekly averages) and our own rainfall gauges were of the non-recording type. A useful proxy might be consecutive rainfall days. For example, the unusual *yala*-01 spill events (described in this section) commenced after two weeks of almost continuous daily rainfall.

On average Anamaduwa received almost 10% more annual rainfall than Galgamuwa (1161mm and 1049mm respectively) over the 18-year period from 1984 to 2001. This is consistent with the proximity of Anamaduwa to the Intermediate zone boundary (Figure 1.2). However comparison of the two data sets using a one-tailed independent samples t-test indicated that these mean levels were not significantly different over the same period ($t(34) = -282$; $p > 0.5$). During the same period, Galgamuwa received annual rainfall levels below the DL1 agro-ecological region 75% probability level (787mm) during three years and Anamaduwa during only two years. All of these 'below average' or 'drought' years occurred prior to 1994. These results correspond with a total of 16% and 11% 'drought' years during the 18-year period; considerably lower than the 1:4 year ratio anticipated for the longer-term 30-year normal period. Nawaratne and Gunawardene (1999) found that the DAS 75% rainfall probability values (Ponrajah 1984) do not uniformly represent the DL1 region due to a marked spatial variation of rainfall, which decreases from east to west. Their data suggests a significantly lower value for the two research areas; between 500 - 600mm. However, this would mean that use of the existing design criteria should result in over-capacity and tanks in turn would fill less rather than more frequently. Results over the 18-year period presented here therefore appear to contradict these findings. They also contradict longer term trends indicating a significant decline in rainfall levels over the 30-year normal period from 1961-1990 compared to the previous 30 years (Nawaratne and Gunawardene 1999, Chandrapala 1997).

Of particular relevance to this study are the years from 1996-2001. This period encompassed the five years over which farmers were asked to asked recall hydrological frequency data (regarding cultivation, seasonality and spill events) as well as the two years, 2000-2001, during which action research took place. All annual rainfall levels during the period were above the 75% probability figure. However, given the discrepancy outlined above it is more instructive to compare these years with mean values obtained over the 18-year period described above. On this basis Galgamuwa recorded two below average, two average and two above average rainfall years, whilst Anamaduwa experienced five above and only one below average rainfall year over the same period (Figure 2.3). Most significantly, the two ‘intervention’ years; 2000 and 2001 received the lowest and highest rainfall in both areas respectively. The 2001 ‘recovery’ came after progressive decline over the previous four years.

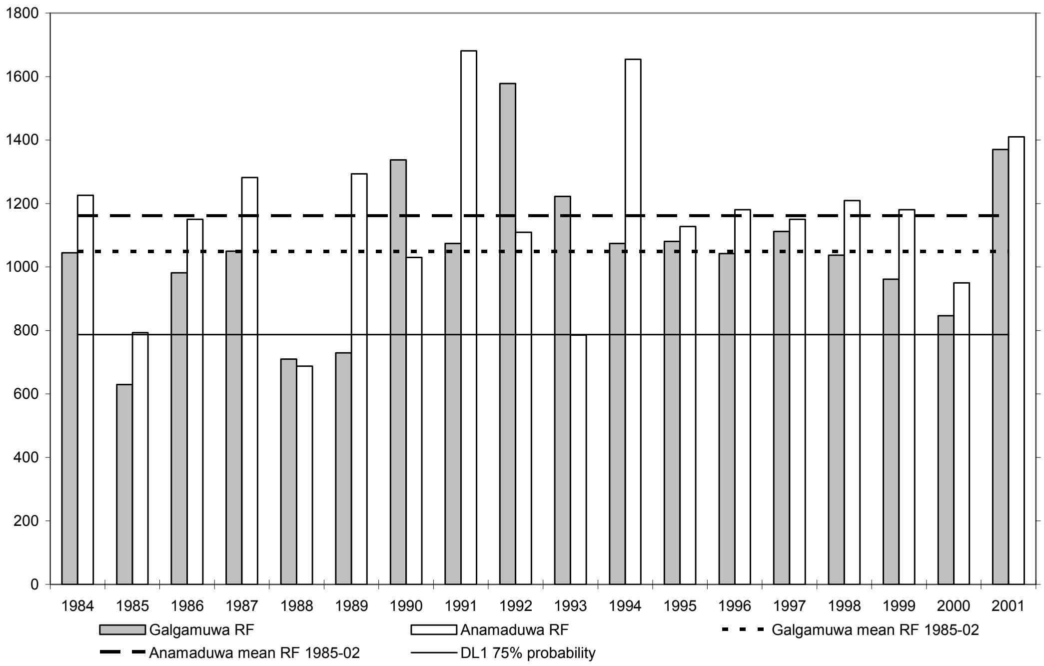


Figure 2.3 Total and mean annual rainfall at Galgamuwa and Anamaduwa, 1984 – 2001 (source; DAS).

Uncertainty associated with the erratic distribution of rainfall is the greatest constraint to agricultural livelihoods in the Dry-Zone (Chapter 5). Mean monthly rainfall levels for the 1995-2001 period are presented for the Galgamuwa area only (Figure 2.4). A high annual co-efficient of variance (17.1%) and wide monthly standard deviation levels reflect high inter-annual and seasonal variability in rainfall distribution. June and July were consistently dry, while the peak rainfall months of November and April are least predictable. In a reversal of the expected bimodal trend, the graph also shows marginally higher mean rainfall in April than October. This was due to the influence of an unusual climatic event in 2001 when 530mm (38% of the year's 1413mm total) fell over 21 days in April. This also had the effect of reversing the normal minor and major cultivation seasons and would also have major impacts on fish production and harvesting practices as described in Chapters 5 and 6. The magnitude of this event is more apparent in Figure 2.5, which shows monthly rainfall during the two project-intervention years alongside the 75% probability values. No other similar reversals were observed in the secondary data set (data not shown), though a key informant from Galgamuwa DAS reported an approximately 20yr likelihood of recurrence in the Galgamuwa area.

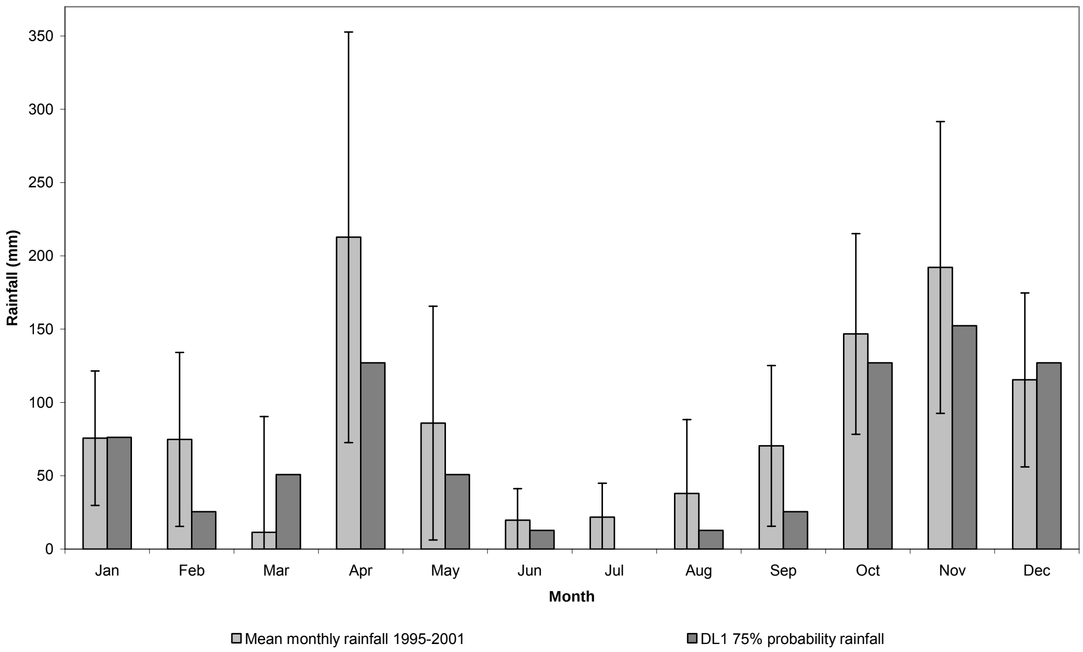


Figure 2.4 Mean monthly rainfall and standard deviation at Galgamuwa, 1995 – 2001 (source; DAS Galgamuwa)

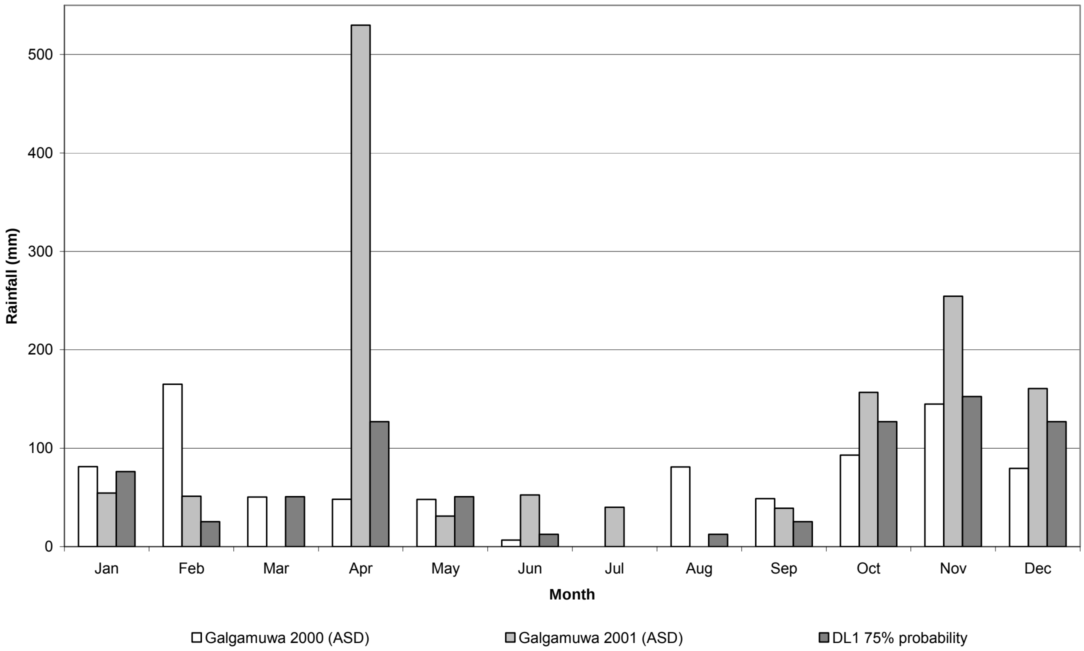


Figure 2.5 Monthly 75% probability rainfall levels for agro-ecological zone DL1 (Ponrajah 1984) and total monthly rainfall recorded by Galgamuwa DAS 2000-2001

A summary of the primary rainfall data collected by research staff in Galgamuwa and farmers living at five intervention sites (2000-2001) is presented in Appendix 11. After the researcher managed site at Galgamuwa, the most reliable records were maintained at farmer sites in DDW, Ihala Maradankadawala (IMK) and Gurulupitigama (GUR). The other sites also reflect general trends reported above, but probably under-report total rainfall levels. Results from the former sites indicate that after three successive years of below average rainfall, 2001 achieved a slightly above average annual total with a mean of 1352mm (recorded at the four most reliable sites over an average of 70 rain days). There appears to be little spatial variation within the area encompassed by the reliable sites with standard deviations of ± 78 mm and ± 6 days for annual rainfall and total rain days respectively. These findings would permit an interpretation of stocking outcomes in the context of longer term climatic trends.

2.3.3 Watershed characteristics and cascade hydrological endowment

A map showing the distribution of tanks in nine adjacent watersheds of the Giribawa area is shown in Figure 2.6. Seven of the nine phase 1 and 2 intervention tanks located in these systems are also indicated. Cascades are named after intervention villages where applicable or alternatively after the largest village in the system. An inventory of names and physical information corresponding with the numbering of tanks in Figure 2.6 are given in Appendix 14. Detailed information and maps relating to four watersheds in Anamaduwa and another isolated cascade in the Giribawa area (Danduwellawe) are given in Murray and Little (2000).

Uncoordinated tank rehabilitation can have adverse consequences for aquatic production. Spill frequency and consequently, fish migration will be reduced in cascades where tank capacity has been over-expanded in relation to gross catchment area. Over-extending 'nodal' axial tanks, which are 'cross-roads' for migration, will result in the most severe bottlenecks. This could effectively isolate tanks in upper catchment areas from perennial tanks and their permanent fish stocks lower in the watershed; with linear systems at greatest risk (see below). In terms of seasonality, tanks that are too small to service their command areas are more likely to be drained at the end of the cultivation season, or alternatively, cultivation may be abandoned entirely during low rainfall years. These problems should be addressed by cascade level planning based on an assessment of overall hydrological endowment, taking the requirements for different water uses into account. Results of our analysis for the Giribawa watersheds, using Sakthivadivels' model (*ibid*) are described below and summarised in Table 2.3.

The most distinctive physical feature of the Giribawa research area is a chain of rocky 'inselbergs' (literally island-mountains; also referred to as 'rock knobs') which run in a south easterly direction. This chain forms the watershed boundary between two adjacent river basins (Kalu Oya to the North and Mi Oya to the south). It is also a natural geographic feature demarcating the administrative boundary between Kurunegala and Puttalam Districts. The Giribawa research area straddles this boundary though only two research watersheds, GBW and KBK, were located on the Puttalam side. Most of the cascades within these watersheds were small and linear, along with one 'medium' (KBK) and one 'large' system (IMK). The three largest systems were branched though with only 1-2 side valleys in each instance. Higher form indices (0.24 - 0.32) correspond with the larger branched cascades. Despite their lower hydrological endowment, these cascades may have better potential for fish migration as bottlenecks are likely to be less severe. All the watersheds fell into a 'flat or nearly flat' 0-2% gradient class, though these measurements exclude the steep and rocky inselbergs that rise out of the plain at the top of many of the watersheds that are still covered with extensive areas of primary and secondary scrub jungle.

The second part of the assessment is based on ratios of catchment, MWS, and command areas together with cropping frequency (CF). Results indicate that command areas of tanks under the larger branched cascades were more likely to be over-extended (with CoW from1.5 to2) than under the smaller linear systems (CoW from 0.8 to 1.2). The storage density (CaW) of the cascades ranged from 7.5 to 23.6. This indicates that none of the cascades were over extended, though GIR, which included the largest tank in the survey, was on the threshold. Both KBK and GBW in recently settled and remoter jungle areas on the Puttalam side of the research area had high CaW and scope for further development, i.e. construction of new tanks or the extension / deepening of existing ones.

CF results are consistent with the succession of low rainfall years during this period. Averaged over each cascade, *maha* cultivation took place from 2 to 3.1 of the five years and *yala* cultivation from 0.5 to 2 years (Table 2.3). During low rainfall years, cultivation is most likely to be abandoned entirely under smaller tanks that provide the most supplementary irrigation. This is the reason for the low CF recorded in MAD and LHG which are comprised entirely of smaller radial and axial tanks.

Despite some high CoW levels, these results indicate that in most cases there would be little benefit from increasing overall tank capacity with the exception of cascades with high combined CaW and CF values such as GBW. Smaller tanks with already low CF and CoW would be least cost effective to enlarge.

Taken together these results indicate that the gross storage capacity in most of the cascades in the Giribawa area is essentially compatible with available catchment area. This contrasts with previous findings from the Anamaduwa area where weighted cascade CaW ranged from 6.6 to 7.1 (Murray 2000c). The higher tank density in these cascades is consistent with the earlier resettlement and longer phase of tank rehabilitation in this area (Chapter 1). Cascade CoW ranging from 1.3 to 1.98 were also indicative of more intense development. Under these circumstances further uncoordinated tank rehabilitation would simply move water deficits downstream with adverse consequences for spill events and fish migration. In addition to these cascade level hydrological effects, de-silting can also affect the nutrient status of individual tanks as illustrated in the following section.

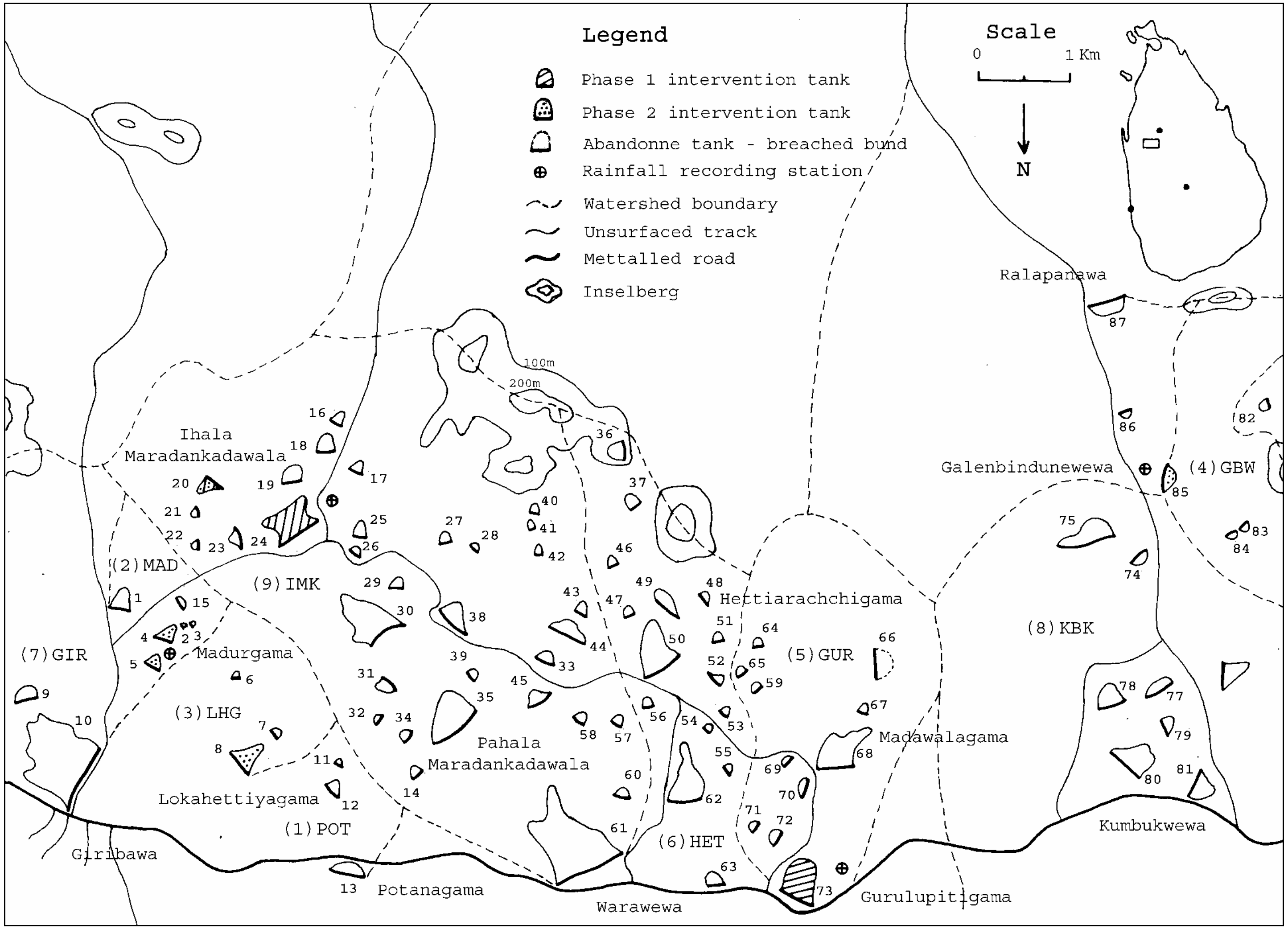


Figure 2.6 Map showing locations of tanks belonging to 13 villages in 9 watersheds of the Giribawa research area (village names are given in full. For explanation of watershed codes, refer to Table 2.3 and for tank codes to Appendix 14)

Table 2.3 Some topographic and hydrologic characteristics of nine watersheds in the Giribawa research area based on the classification system of Sakthivadivel *et al.* (1997). Watersheds are shown in order of increasing size.

Watershed[1]	Gross area (ha)			Main axis km	Form Index	Form	CaW	CoW	CF	
	Catchment	**Tank MWS**	**Command**						***Maha***	***Yala***
1. POT	117.5	12	NC	1.5	0.08	L	9.8	NC	NC	NC
2. MAD	196.3	18.4	19	1	0.2	L	10.6	1.03	2.5	0.5
3. LHG	216.3	15.6	13.4	1.3	0.12	L	13.9	0.86	2	0.5
4. GBW	440	26.3	22.1	1.8	0.24	L	16.7	0.84	3.5	2
5. GUR	662.5	71.36	82.6	4.4	0.15	L	9.3	1.16	3.1	2
6. HET	697.5	54	104.9	4.3	0.16	L	12.9	1.95	2.1	0.7
7. GIR[3]	835	111.4	NC	3.5	0.24	B	7.5	NC	NC	NC
8. KBK	1118.8	47.43	NC	3.5	0.32	B	23.6	NC	NC	NC
9. IMK	2260	127.9	196.7	7.3	0.31	L-B	17.6	1.54	2.5	0.5

[1] POT = Potanagama, MAD = Maduragama, LHG = Lokahettiyagama, GBW = Galenbindunewewa, GUR = Gurulupitigama, HET = Hettiarachchigama, GIR = Giribawa, KBK = Kumbukwewa, IMK = Ihala Maradankadawala (see Figure 2.6) [2] L = Large, B = Branched
[3] GIR calculations also incorporate MAD which is a tributary micro-watershed

2.3.3.1 Tank rehabilitation

This section will briefly summarise the recent repair and maintenance history of the tanks in the research watersheds including the intervention tanks. Such 'rehabilitation' works include: bund strengthening, sluice and surplus weir repairs or installation and de-silting. Phase 1 trials (Chapter 5) indicated that tank de-silting activity had the following positive and negative impacts on aquatic production *in-situ*: (1) the activity usually necessitates dewatering and temporary loss of fish stocks (2) removal of the organic surface layer can dramatically reduce primary productivity during the subsequent season, depending on the extent of the activity (3) deepening of the area close to the bund can temporarily remove encroaching aquatic macrophytes, thereby increasing catch per unit effort during collective fishing events, and provide a refuge for the remaining population during the dry season.

In order to generalise the significance of these findings, the prevalence of de-silting works during the five years prior to the first phase of trials was compiled for a sample of 120 tanks in the Giribawa and Anamaduwa watersheds. Of all maintenance works, de-silting is the most costly and therefore least frequently implemented activity. Consequently, full de-silting was restricted entirely to the smallest axial 2 or lower order tanks and implemented in only 6.7% of the sample number, while partial de-silting had taken place in an additional 14.3% of the tanks (Figure 2.7). In absolute terms this meant that more radial tanks were de-silted than any other category, though they received least attention in proportion to their total number (62% of the entire sample).

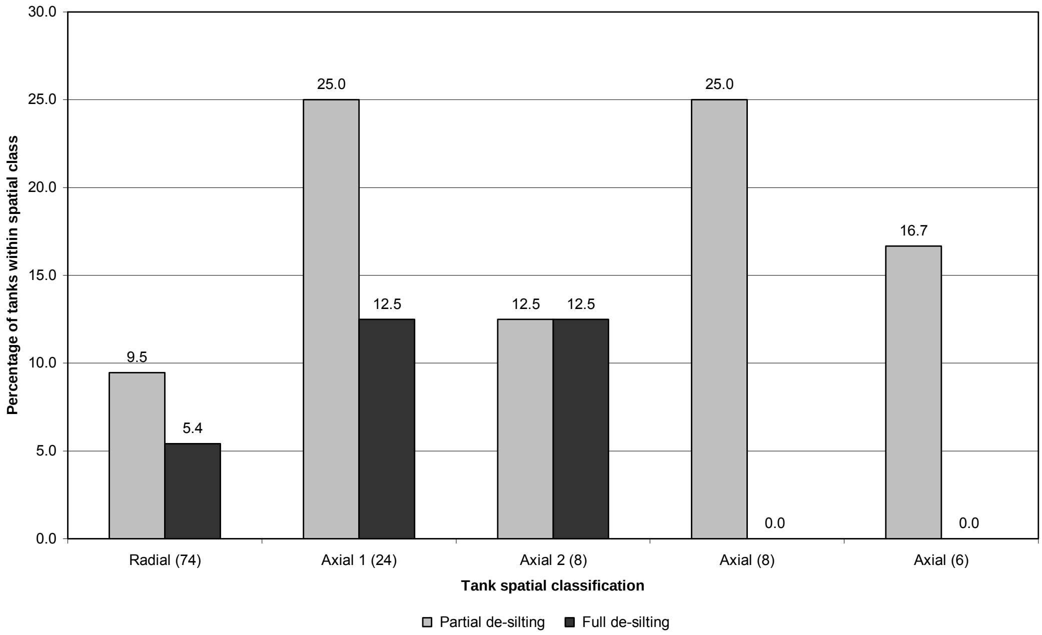


Figure 2.7 Percentage of tanks in Anamaduwa and Giribawa research areas having undergone partial or full de-silting between 1995-2000 (bracketed numbers indicate the total number of tanks in each spatial class)

Results also corresponded with the policy directions of different implementing agencies outlined in Chapter 1. NGOs were responsible for directly implementing de-silting works only in smaller tanks; axial 2 or less. This was consistent with their policy of targeting poorer communities while the scale of such works also corresponds with their logistical and budgetary capacity. Major works in larger seasonal / perennial tanks, which are more cost effective in terms of net benefits going to the largest numbers of beneficiaries, were exclusively the preserve of Government line agencies, principally the DAS. However in both cases works requiring mechanised plant were invariably assigned to external contractors with token farmer participation.

Key informant interviews revealed that all the intervention tanks had benefited from some type of rehabilitation work on at least one occasion since 1995. This included sluice repairs in every case, while three of the smaller tanks; SER, LUN, GBW had permanent surplus weirs / culverts installed for the first time. Subsequently, only the smallest tank KRB retained a simple earthen weir (section 2.3.6.1). Such minor repairs were frequently undertaken by local villagers in exchange for *Samurdhi* welfare benefits (Chapter 4). Prior to the installation of gate sluices between 1995-97 the bunds of KRB, LUN and SER had to be 'cut' to issue irrigation water in a relatively uncontrolled and wasteful manner. Only the two largest tanks IMK and LHG had concrete bathing steps. This was justified both in terms of their greater bund height and the large size of adjacent populations using the facility. Partial de-silting had recently taken place in the largest tanks; LHG, IMK, GUR which had the dead storage areas (DSA) beneath their bunds deepened. Two (radial) intervention tanks in the Anamaduwa research area; Ulpathwewa and Keeriyagahawewa (Plate 2.3), tanks, were both fully de-silted by a local development agency six months prior to stocking (Chapter 5).

Plate 2.3 Keeriyagahawewa; a radial tank in the Anamaduwa research area, partially filled, two months after being fully renovated in September 1999. Works included, full de-silting, surplus weir, sluice and bund repairs.

2.3.3.2 Tank operational status

Most tanks in the survey could be described as 'working' in as much as they supported paddy cultivation, though with various degrees of periodicity, cropping and irrigation intensity. There were only two truly 'abandoned' tanks that had ceased to support any cultivation for many years; Maha Madawalagama (5ha) and Kivulwewa (1ha). These are both radial tanks consisting only of simple earth works isolated in deep jungle areas of the Giribawa area (Figure 2.6). The larger of the two had a breached bund so that its net catchment area is effectively incorporated into that of the tank immediately beneath it. Pannabokke, Sakthivadivel *et al.* (2002) estimate that 35% of tanks in NWP are 'abandoned', though they give no precise definition of this status. Presumably, many of the periodically cultivated highly seasonal tanks in our current survey would fall within their definition.

In the rest of this section, I will briefly consider two additional tank types encountered in the survey. Bulnewa, a small tank (0.8ha) axially located at the top of the Galenbindunewewa cascade, was the single example of what farmer characterized as an *ammuna* or drainage tank. As their name suggests, such tanks rely mainly on the interception of drainage returns for their supply. They consist of a temporary earthen bund which must be 'cut' open to permit irrigation releases and repaired on an annual basis. Such tanks are highly seasonal holding water for no more than four months during the main irrigation season and are typically privately owned / managed smallholdings. Unlike conventional axial tanks they are connected by spill events only to lower tanks and are therefore classed as radial despite their intermediate position (section 2.1.2).

Finally the survey included seven small (0.05-0.2 ha) highly seasonal privately owned radial tanks located within or at the interface of home-garden / jungle areas. They are used primarily for domestic and livestock purposes, but also occasionally for supplementary irrigation of nurseries or cash crops with relatively low water requirements. Like the abandoned tanks and *ammuna*, they also have no permanent head works (i.e. sluice or concrete spill). The highly seasonal nature of each of these three varieties of tanks means they are intermittently populated by the hardier blackfish varieties (section 2.3.5.1) and generally poorly suited for stocking interventions.

2.3.3.3 Estimating the extent of the village tank resource

As noted in section 2.1.3, estimates of the number of small village tanks in Sri Lanka vary widely between different sources. Furthermore, they generally give no clear indication of operational status (section 2.3.3.1). Ranatunge (1979) has edited the most up to date inventory of tanks of all sizes covering the whole country. A major advantage of this survey is that tanks were numbered serially within each river basin using an older series of one-inch: 1mile (1:63,360) scale topographic survey maps (GoSL Survey Dept. 1959). According to this source, the total number of minor tanks, restored and abandoned in the country is 18,378. Wijetunga (1986) has made the highest estimate of tank numbers. He found that many abandoned tanks have escaped survey because of their inaccessibility; being widely dispersed and often still covered in scrub jungle. He estimates that inclusive of these tanks, the total number is around 30,000, of which approximately 7,000 are still working and supporting regular crop cultivation by local communities. The Department of Agrarian Services (DAS), the line agency responsible for minor tanks, estimated a similar number of 7,620 'working' tanks along with a total of 7,753 'abandoned' tanks in 1995, i.e. 15,373 tanks. However, the long running ethnic conflict has made it all but impossible to investigate the Northern and Eastern Provinces for over 20 years. Consequently, the latter estimate is also based on primary data collected prior to 1982.

Wijetunga's assertion relating to the 'invisibility' of smaller tanks remains the most compelling explanation for the ongoing uncertainty. This is underscored by the most recently available information relating to size class distribution. Data for the four districts with the highest tank densities (Anuradhapura, Puttalam, Kurunegala and Hambantota) was updated in 1997 by the DAS as part of an ongoing survey in 17 of the 25 administrative districts. This revealed that 47% of tanks fell into the smallest <6ha command area (CA) size class, while 86% were less than 20ha (Figure 2.8). The proportion of smaller (<6ha CA) tanks in Kurunegala District was considerably higher than in any of the other districts, both in absolute (2873 tanks) and relative terms (64% of the district total). The same class constituted 45% of tanks in Puttalam District, although numbering only 339 tanks. Pannabokke *et al* (*ibid*) attribute this abundance to a corresponding high number of inselbergs in NWP, which present ideal terrain for small tanks in upper-watershed areas.

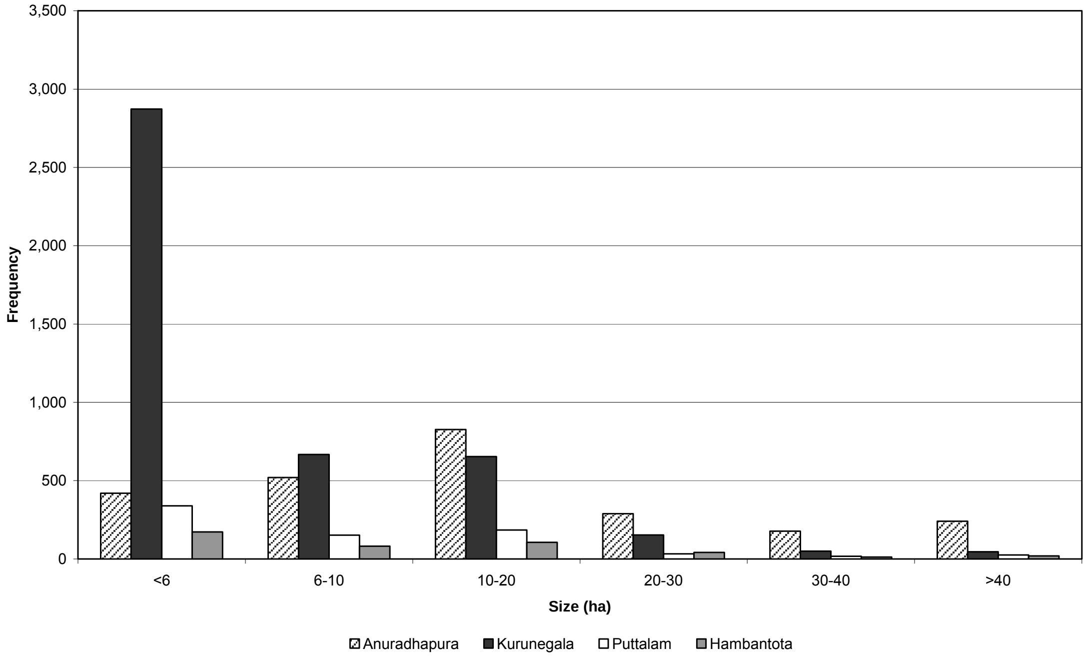
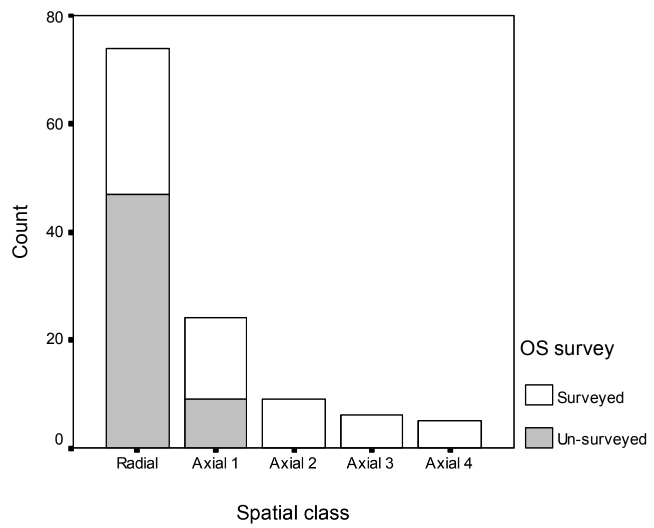


Figure 2.8 Size class distribution of tanks based on command area in four districts (after Pannabokke, Sakthivadivel *et al.* 2002)

In our current survey, some 47.5% of all tanks in both research areas (n = 120) were still unmarked on the most recent 1:50,000 survey maps (GoSL 1988, Figures 2.9.A). When perennial tanks (n = 13) are excluded, the proportion is equivalent to 52.3% of tanks in Giribawa (Kurunegala District) and 31.6% in Anamaduwa (Puttalam District). All of these tanks fall within the 'radial' and 'axial-1' spatial classes corresponding with the 'highly seasonal' and 'semi-seasonal' seasonality classes. Despite their small size, together they constitute 19.8% of the total cumulative water-spread area at FSL inclusive of perennial tanks (Figures 2.9.B). Further analysis of size-class distribution is presented in section 2.3.4.1 .

These results suggest that the true number of tanks is likely to be closer to the figure of 30,000 estimated by Wijetunga (*ibid*), than the 18,000 estimated by Ranatunge (*ibid*). It is more difficult to compare our results with those of the more recent DAS survey described above. Despite attempts to collect information from local DAS offices, no detailed disaggregated information was available although some *Grama Niladhari* did keep their own personal inventories. Consequently, it appears that the true extent of the resource still remains invisible even to local planners.

The seasonality of these smaller tanks and their high propensity for occlusion by aquatic macrophytes (Appendix 22 and Appendix 23) are also cited as reasons for exclusion from state sponsored stocking programmes based on exotic carps (Chapter 5).



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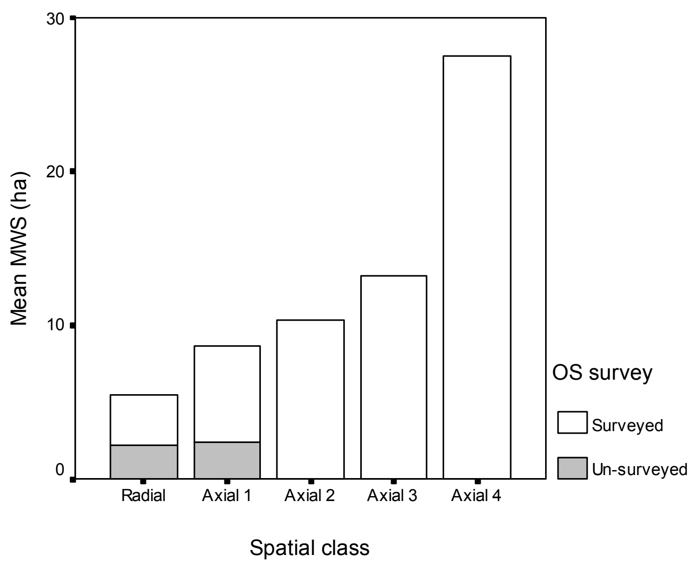


B

Figures 2.9 A and B: Frequency distribution (A) and cumulative MWS area (B) of surveyed and un-surveyed tanks (1:50,000 GoSL Survey Department maps 1988) tanks within spatial class groupings

2.3.4 A tank typology based on aquatic production potential

Having classified the cascade systems according to some basic topographic and hydrological parameters, in this section, I attempt to produce a corresponding typology based on natural aquatic production potential.

Amongst the many bio-technical determinants of aquatic production in village tanks, two hydrological factors are of primary importance. Firstly, seasonality characteristics determine the ability of breeding age fish (‘brood-stock’) to persist over the dry season. Secondly, surplus-weir design has a critical impact on the potential of fish to migrate and repopulate tanks that may have lost some or all of their stocks during the dry season. Weir design has two consequences for migration; (1) it will determine the periodicity and duration of spill events and (2) poorly designed weirs might present an insurmountable obstacle to migration when spill events are under way (section 2.3.6).

Traditional tank classification systems (Chapter 1) are based around the primary irrigation function of tanks and are therefore of little practical use in gauging these criteria. Clearly, the optimal design requirements for fish production are not always likely to correspond with those for other uses. For example, for reasons of economy, village tanks are designed to minimise residual storage and to produce relatively infrequent spill events (sections 2.3.5 and 2.3.6). Spill events are also perceived as a constraint for conventional culture-based enhancement strategies as they increase the risk of escapes.

A useful typology of aquatic production potential would correlate seasonality and spill characteristics with one or more easily measured physical tank characteristics or on farmer recall of historic events. Two systems were devised corresponding with these approaches; one placing tanks into one of four seasonal classes based on drying periodicity and fish survival potential using farmer recall data, and the other using spatial location within the watershed as a proxy of hydrological status. (Table 2.4)

However, whereas survival of fish stocks will depend to a large extent on residual / dead storage characteristics, spill frequency is influenced by a wider range of *in-situ* and *ex-situ* factors such as tank density and gross catchment area. Spill-frequency is therefore likely to be less closely correlated with individual tank size and location than seasonality. In the following sections, I assess the strength of correlations between physical tank characteristics; water-spread area and spatial class, with farmer recall on seasonality and spill-frequency in the two research areas.

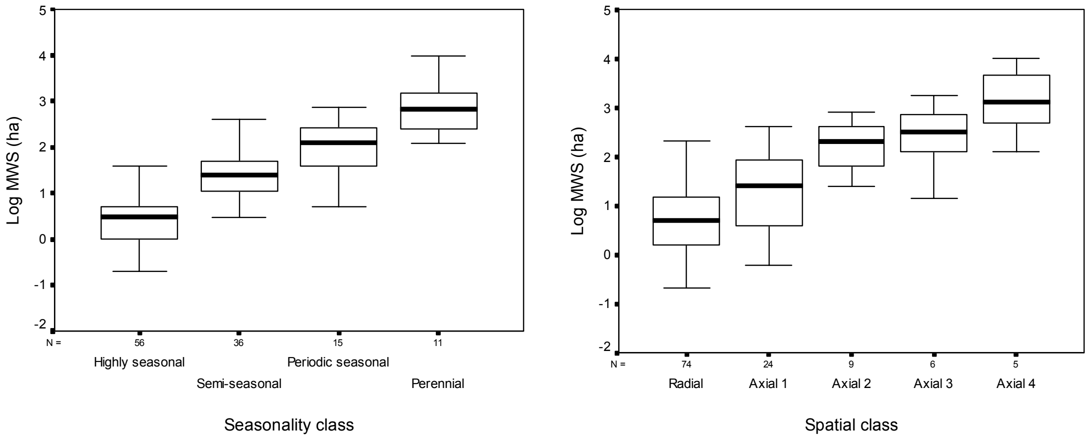
Table 2.4 Putative tank typologies based on spatial, seasonality and aquatic productivity criteria

Class	Code	Description
1. Seasonality classification based on farmer recall		
Highly Seasonal	HS	Dries completely 4-5 years out of every five years with loss of resident fish population
Semi Seasonal	SS	Dries in 1-3 years out of every five years with loss of resident fish population
Periodic Seasonal	PS	Dries less than once every five years with loss of resident fish population
Perennial	P	Has not dried in recent memory other than for rehabilitation works
2. Spatial classification based on cascade position		
Radial	R	Receives water only from own micro-catchment
Axial 1	A1	Receives water from one or more radial tanks
Axial 2	A2	Receives water from one or more Axial 1 tanks
Axial 3	A3	Receives water from one or more Axial 2 tanks
Axial 4	A4	Receives water from one or more Axial 3 tanks
Axial 5	A5	Receives water from one or more Axial 4 tanks etc.

2.3.4.1 Correlation of tank size with spatial and seasonal typologies

The purpose of this analysis was twofold; to assess how far the categories in the two typological systems described in section 2.3.4 corresponded with discrete ranges of tank size, and to examine whether any significant differences were consistent between the two geographically isolated research areas. To answer these questions a between subjects multi-factorial analysis of variance (ANOVA - SPSS 12) was repeated for ‘seasonality’ and ‘spatial’ class as independent grouping factors. For each repetition, ‘research area’ was the second independent factor while ‘MWS area’ was the dependent variable.

The pooled data were tested to ensure assumptions of the ANOVA test regarding normality and homogeneity of variance were met. Box plots revealed highly positively skewed frequency distributions due to the relative abundance of smaller tanks in each category. The dependent variable was therefore transformed in order to achieve log-normal distributions in each case. Subsequent box plots revealed one remaining outlier, Pahala Giribawa (PGB). At 89ha, this was 40% larger than any other tank in the survey, with the exception of Uriawewa (84ha) in the Anamaduwa area; the only system tank in the sample. Both these tanks were discarded, leaving 118 ‘rainfed’ tanks in the sample, (i.e. receiving water only from their gross catchments), 38 in Anamaduwa and 80 in Giribawa, whose transformed distributions are shown in Figures 2.10 A and B.



A **B**

Figures 2.10 A and B: Box plots for tank Log10 MWS area data grouped by (A) seasonality and (B) spatial class (data pooled for Giribawa and Anamaduwa research areas)

Next, these transformed distributions were statistically tested for normality using the Kolmogorov-Smirnof test (Table 2.5). Results indicated 4 significant factor conditions; ‘highly seasonal’, ‘semi-seasonal’, ‘radial’ and ‘axial 1’ ($P < 0.05$) while weaker normal approximations (P 0.17 - 0.2) were obtained for the remaining conditions which included smaller numbers of larger tanks (Table 2.3). The residual skewness of the latter groups is evident in the box plots shown in Figures 2.10 A and B. Consequently, ANOVAs were repeated with the weakly normal conditions both included and excluded.

Table 2.5 Results of Kolmogorov-Smirnov tests of normality Log10 MWS (ha) frequency distributions within seasonality and spatial factor conditions

Seasonality class	Statistic	df	Sig.	Spatial class	Statistic	df	Sig.
Highly seasonal	0.148	56	**0.004**	**Radial**	0.122	74	**0.009**
Semi-seasonal	0.155	36	**0.028**	**Axial 1**	0.171	24	**0.047**
Periodic seasonal	0.185	15	0.177	**Axial 2**	0.235	9	0.166
Perennial	0.110	11	0.200	**Axial 3**	0.223	6	0.200
				Axial 4	0.165	5	0.200

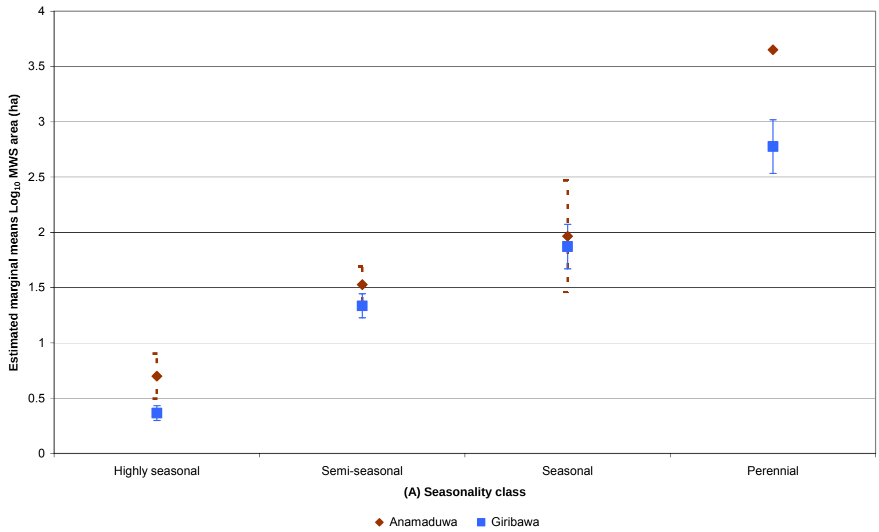
Results show highly significant differences ($P < 0.01$) between each of the seasonal and spatial factor conditions for each of the four ANOVA (Table 2.6). In other words, mean tank size corresponds with the ordering of categories in the seasonal and spatial typologies as might be expected. However, there was only one significant difference between the two research areas. This was for seasonality inclusive of all factor conditions

(ANOVA: F (1,109) = 4.45; P = 0.037). In other words the average size of tanks in the different seasonality classes was larger in Anamaduwa despite its marginally higher rainfall levels. The likely reason for this is discussed below. No significant interaction effects were recorded in any instance.

Table 2.6 Results of between subjects multi-factorial ANOVA for the dependent variable Log10 MWS (ha)

Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Tests inclusive of all factor conditions					
1. Inclusive of all seasonality factor conditions					
Seasonality class	35.51	3	11.84	40.88	**0.000**
Research area	1.29	1	1.29	4.45	**0.037**
Seasonality * Research area	0.49	3	0.17	0.57	0.637
2. Inclusive of all spatial factor conditions					
Spatial class	27.93	4	6.98	15.34	**0.000**
Research area	0.00032	1	0.00032	.001	0.979
Spatial * Research area	3.23	4	0.81	1.77	0.140
Tests on subsets of factor conditions					
3. Highly seasonal and semi-seasonal seasonality factor conditions only					
Seasonality class	11.52	1	11.52	44.06	**0.000**
Research area	0.98	1	0.98	3.75	0.056
Seasonality * Research area	0.072	1	0.079	0.28	0.601
4. Radial and Axial 1 spatial factor conditions only					
Spatial class	2.755	1	2.76	5.76	**0.018**
Research area	1.730	1	1.73	3.67	0.060
Spatial * research area	0.098	1	0.098	0.21	0.651

These results are more readily interpreted from plots of the marginal means of tank size for each of the spatial and seasonality classes in each research area (Figures 2.11 A and B). Tanks in Anamaduwa are consistently larger than in Giribawa in all but the Axial 3 spatial class. This overall trend is consistent with the lower CoW and CaW ratios and relatively poorly coordinated tank rehabilitation in the longer settled Anamaduwa area (section 2.3.3). The axial 3 'inversion' is due to the effect of a single tank Ihala Sembugama (ISM) in the Anamaduwa area which was substantially smaller than a superior axial tank. A similar inversion occurred in the MAD cascade; this time associated with KRB, an intervention tank. However, in this instance, the effect was masked by a larger sample size. As indicated above, the effect of these two inversions was insufficient to cause a significant interaction effect.



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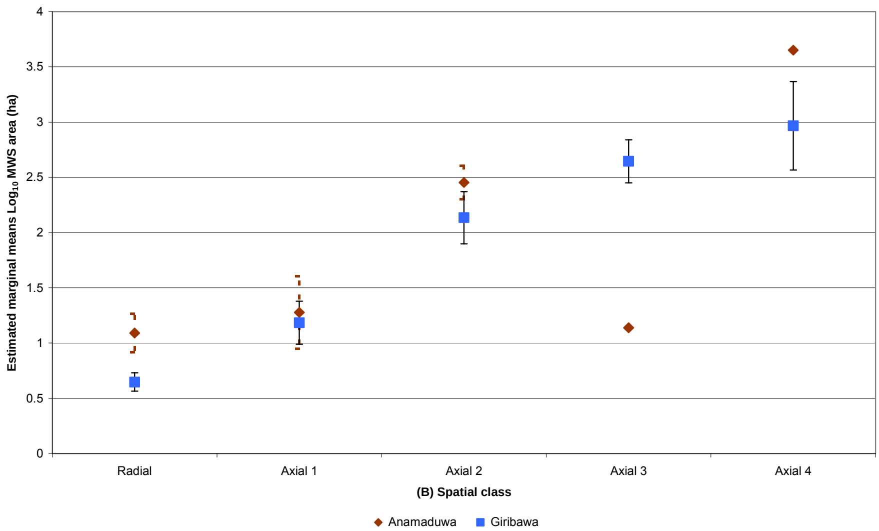


B

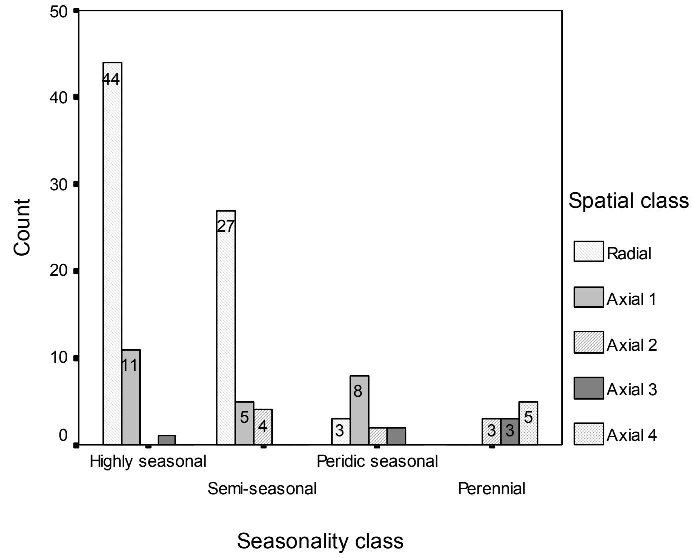
Figures 2.11 A and B: ANOVA marginal means and SEM of Log_{10} MWS area (ha) data grouped by (A) seasonality and (B) spatial class for 118 tanks in Anamaduwa and Giribawa research areas

In the rest of this section, I will present a more detailed descriptive analysis of the typological classes. Although the previous analysis revealed significant differences between research areas, these differences were relatively marginal and consequently, data is pooled for this assessment.

As noted above tank distribution is highly positively skewed in favour of smaller tanks; 47.5% and 30.5% of tanks fell within the highly and semi-seasonal classifications and 62.5% and 19.5% in the radial and axial 1 radial categories respectively (Figures 2.12.A).

Conversely, mean water-spread area is negatively skewed (Figures 2.12.B). Perennial and axial 4 tanks contribute 47.7% of 35.3% of total area although they represent only 10.1% and 5% of the total tank number respectively.

More significantly, Figures 2.12 A and B also show that while all axial 4 tanks fall into the perennial seasonality class, all other spatial classes overlap three consecutive (radial, axial 1, axial 2) or non-consecutive seasonality classes (axial 3). Within these categories the degree of overlap tends to increase with increasing spatial order; radial tanks having a relative combined occurrence of 96% (n = 74) in the highly or semi-seasonal classes whilst axial 3 tanks range from highly seasonal (Ihala Sembugama) to perennial (n = 6). Cross-tabulations of the same data sets are also presented in Appendix 13.



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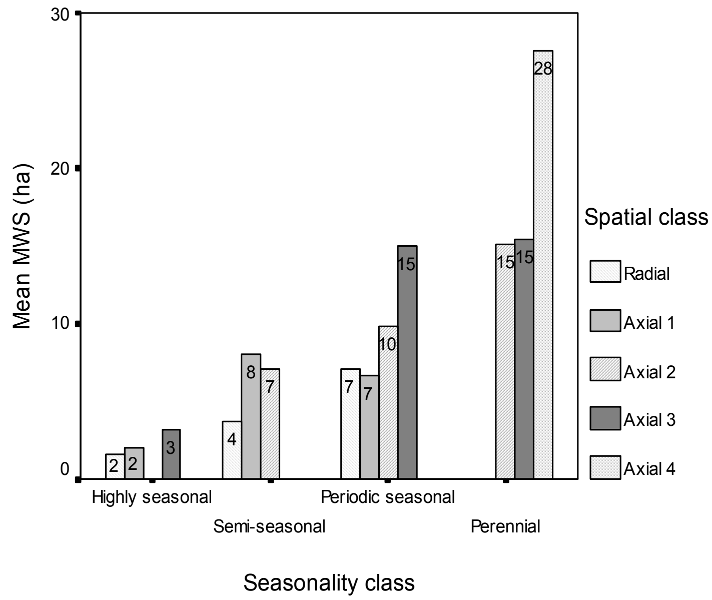

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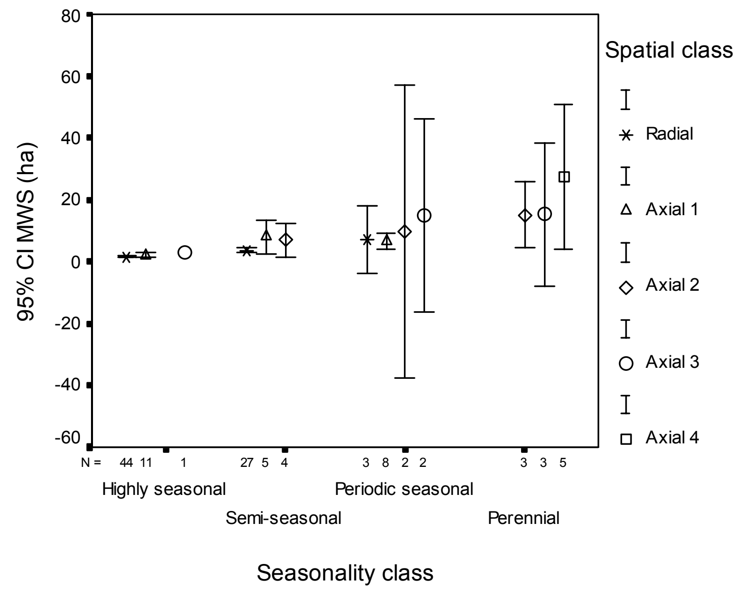
Figures 2.12 A and B: Distributions of (A) frequency and (B) MWS area, for all survey tanks within seasonality and spatial-class groupings

Figures 2.13 A and B, show the 95% confidence intervals (CI) for population class means based on the sample data. The higher order conditions in each factor exhibit much wider limits because of their smaller sample size and higher variance. These results are combined with summary MWS area data (Table 2.7) to derive usable limits for each class associated with a known probability. Upper limits are based on the upper 95% confidence limit for the mean, plus 2 standard deviations (i.e. incorporating 95% of all sample values). In order to avoid illogical negative values, lower estimates are based on the minimum observed values in the sample. Results are presented graphically in Figure 2.14. Upper estimates for perennial tanks (italicized in Table 2.7) are arbitrarily imposed by the sample cut of point.



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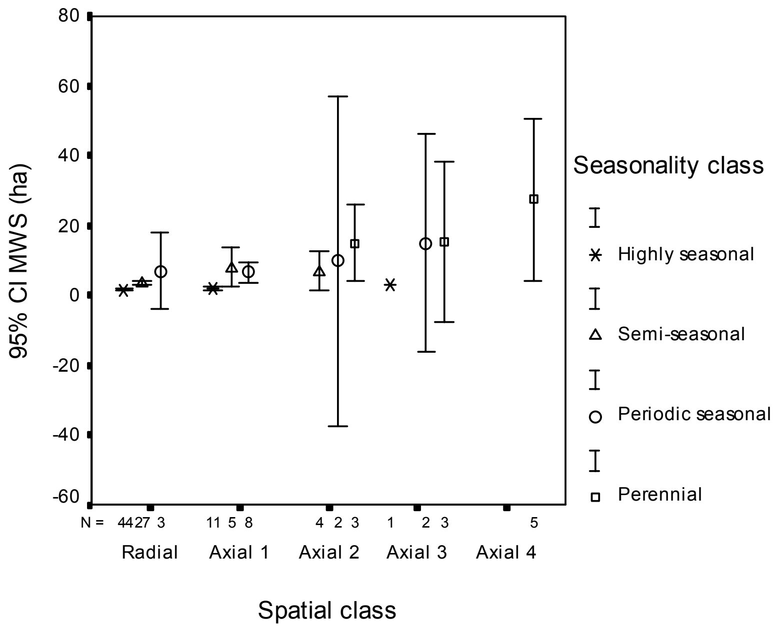

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Figures 2.13 A and B: 95% confidence intervals for MWS area means grouped by (A) seasonality and (B) spatial class

Results indicate that the simple spatial classification system captures too little of the variability in these cascade systems to be a useful predictor of seasonality for tanks located in the middle of watersheds. An improved, though more complex index, might incorporate the actual number of tanks in every superior category for a given tank or gross-catchment and tank area ratios. However, it is safe to conclude that the highly seasonal and semi-seasonal tanks that are of primary interest here fall into the radial and axial 1 classes of the existing system with very few exceptions.

Table 2.7 Summary statistics for MWS area and limit estimates within seasonality and spatial classes

1. Seasonality class	**Highly seasonal**	**Semi-seasonal**	**Periodic Seasonal**	**Perennial**	
Mean (ha)	1.71	4.65	8.23	20.82	
N	56	36	15	11	
95% mean CI ±	0.23	0.97	2.45	9.57	
STD (ha)	0.84	2.89	4.43	14.24	
Maximum (ha)	4.86	13.56	17.41	54.2	
Minimum (ha)	**0.5**	**1.62**	**2.02**	**8.1**	
Upper estimate (ha)*	**3.62**	**11.4**	**19.54**	***58.87***	
2. Spatial class	**Radial**	**Axial 1**	**Axial 2**	**Axial 3**	**Axial 4**
Mean (ha)	2.58	4.79	10.33	13.2	27.53
N	74	24	9	6	5
95% mean CI ±	0.44	1.62	3.96	8.24	23.27
STD (ha)	1.91	3.8	5.16	7.85	18.74
Maximum (ha)	10.12	13.56	18.1	25.9	54.2
Minimum (ha)	**0.5**	**0.81**	**4**	**3.13**	**8.1**
Upper estimate (ha)*	**6.84**	**14.01**	**24.61**	***37.14***	**88.28**

* = (Mean + ‘95% CI ±’) + (STD * 2)

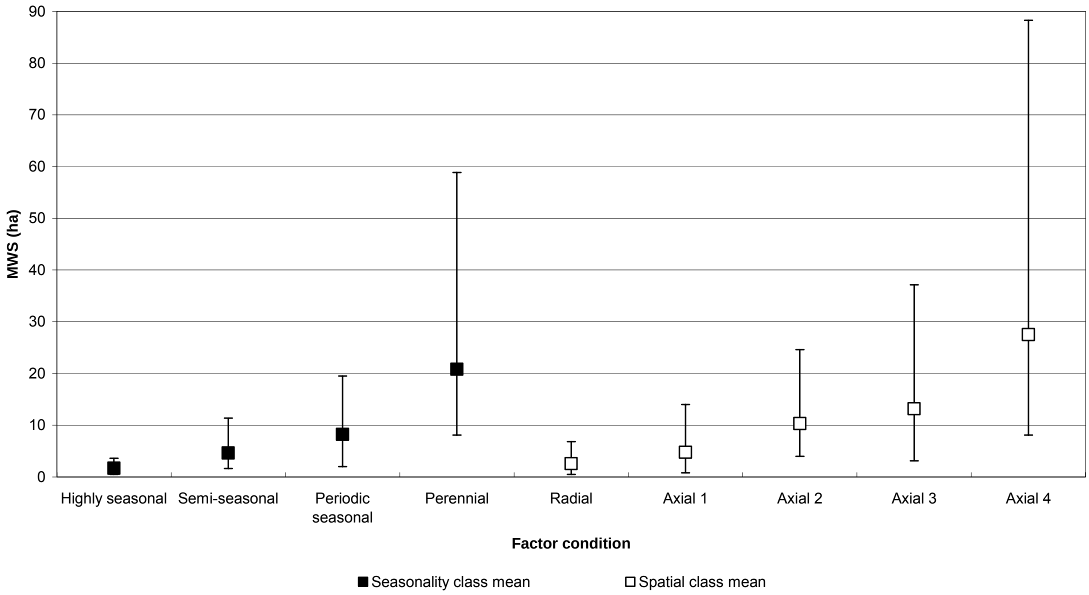


Figure 2.14 Graph showing MWS limits for seasonality and spatial classes (upper limits based on +95% CI for means, plus 2 STD, lower limits based on actual observation)

2.3.5 Seasonality characteristics: drying duration and periodicity

In this section, further detail is given on the drying duration and the periodicity of drying events over a 5-year period. In larger perennial reservoirs sluice-sill elevation (i.e. DSL) is engineered to provide sufficient dead storage area to accommodate silt build-up over a prolonged period. By contrast, minor systems are designed to provide the minimal dead storage given considerations of topography and command area maximisation in order to minimise construction costs. Limited storage is retained for livestock, bathing and other domestic purposes during the dry season. In practice such determinations are simply a matter of judgment based on ensuring sufficient water retention to meet a good part of the dry season evaporation loss, rather than on prescribed design criteria (Shanmughan, Irrigation Training Institute, Galgamuwa, pers. comm., Ponrajah 1994).

Drying Duration

Farmers were asked to estimate the maximum duration of any inter-monsoonal tank 'drying' episodes over the 5-year period from *maha* 1996 to *yala* 2001 (Table 2.8). One-way ANOVA revealed significant differences (F: 12.65, $P < 0.01$) in the mean duration of drying of the three non-perennial tank classes between May to October. *Post hoc*, pair-wise comparisons (Tukey's test) indicated significant differences between highly seasonal tanks ($P < 0.01$) and the two other conditions, but not between semi-seasonal and periodic seasonal tanks ($P = 0.6$). These results correspond with a mean maximum drying period of nearly 2 months for the highly seasonal tanks and between 2-3 weeks for the others. August and September were the driest months.

Direct observation revealed that only five tanks dried during the first inter-monsoonal period; February to April in 2001. Drying times ranged from 2-5 weeks. Four of these tanks were highly seasonal and three had breached bunds. Ihala Sembugama (section 2.3.4.1), a periodic-seasonal tank, was the single axial tank in this category.

Together, these findings indicate that during the sample period, highly seasonal tanks were likely to hold water on average for a minimum of nine months, while semi-seasonal and all periodic-seasonal tanks were likely to hold water for at least eleven months.

Table 2.8 Summary of farmer recall on maximum duration of dry periods, *maha* 1996 to *yala* 2001 (n = 39)

Seasonality class	Highly seasonal	Semi-seasonal	Periodic-Seasonal	Total N
Inter-monsoon-period 1 (Mar – May)				
Mean max. wks	5.0	NA	2.0	
STD Mean max. wks	3.8	NA	0.0	
Month range	Mar - May	NA	Mar - Apr	
Modal dry month	April	NA	April	
n (tanks)	4	0	1	5
Inter-monsoon period 2 (May – Oct)				
Mean max. wks	7.3	3.3	1.8	
STD Mean max. wks	4.4	3.2	0.0	
Month range	May - Oct	Jul - Oct	Jul - Sept	
Modal dry months	Aug / Sept	Aug / Sept	Sept	
n (tanks)	46	22	9	77

Drying periodicity

Key informant data on drying periodicity during the main dry seasons between 1997 and 2001 was collected for a randomized sub-sample of highly seasonal (n = 14) and semi-seasonal tanks (n =11). The highest drying frequency occurred in both classes during 2001. Fewer tanks dried during the previous two years even though they had less rainfall

(Figure 2.15). This is a consequence of the 2000 / 2001 seasonal rainfall inversion (section 2.3.2) which delayed irrigation demand, thereby leaving only minimal residual water storage at the start of the main dry season. Conversely during the previous two years poor *maha* and *yala* rains resulted in many smaller tanks being abandoned entirely for cultivation; leading to more water being retained over a longer period of the year (section 2.3.3). Paradoxically, therefore there may be greater potential for aquaculture in drier years.

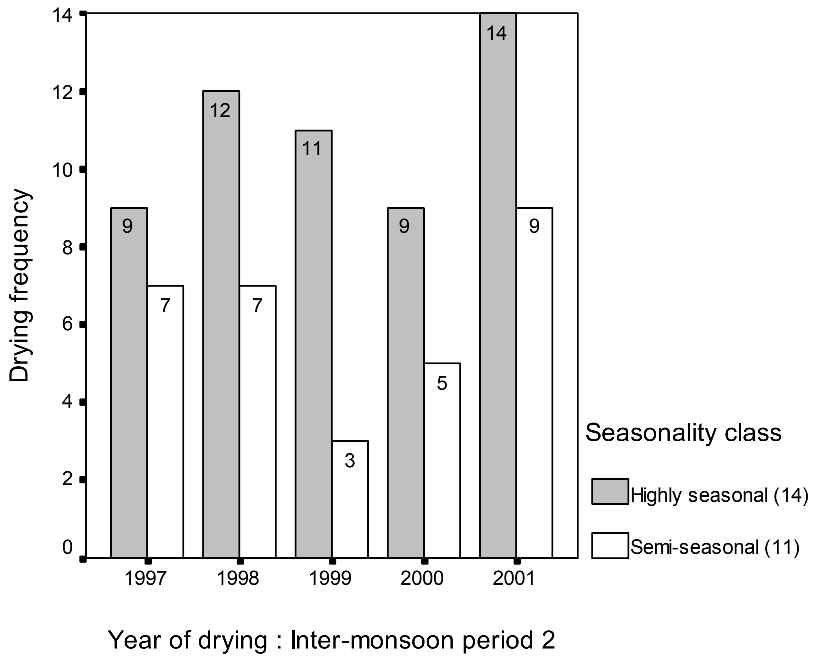


Figure 2.15 Graph of drying periodicity during the main dry season (July to October) for highly seasonal and semi-seasonal tanks from 1997 to 2001

2.3.5.1 Seasonality and fish survival

Based on the results of key informant reports and test fishing in residual water bodies between August and September 2000, 91 tanks in the Giribawa area were further categorised according to their fish survival characteristics. This classification was based on a nomenclature derived from the ecology of sub-tropical flood plain fisheries that also experience highly seasonal fluctuations in water availability (Table 2.9). Fish species in these systems fall into one of two broad groups based on their dry season survival strategies; *whitefish* that will migrate long distances to find shelter in larger deeper water bodies and *blackfish* which are capable of surviving harsh conditions in residual pools *in-*

situ (Hoggarth *et al*. 1999a). Blackfish are also mainly upper trophic level species, i.e. omnivores and carnivores.

Tanks were placed into one of four groups based on the survival potential of different groups of fish (Table 2.9). Class 1 tanks either dried completely or conditions in residual pools became too extreme to support fish life. Survival in class 2 tanks was restricted to the most durable air-breathing 'blackfish', principally climbing perch (*Anabas testudineus*: Plate 2.4) and snakehead (*Channa striata*). Class 3 water-bodies were characterized by the presence of other moderately hardy black-fish varieties principally tilapia, catfish (*Mystus* spp., *Heteropneustes* spp.) while other, less hardy varieties, mainly cyprinids (*Puntius* spp., *Rasbora* spp.) could survive only in class 4 tanks. Larger migratory whitefish, including riverine cyprinids and catfish were encountered only in major irrigation systems. Impassable surplus weirs below many larger perennial tanks clearly inhibited white fish migration (section 2.3.6.1).

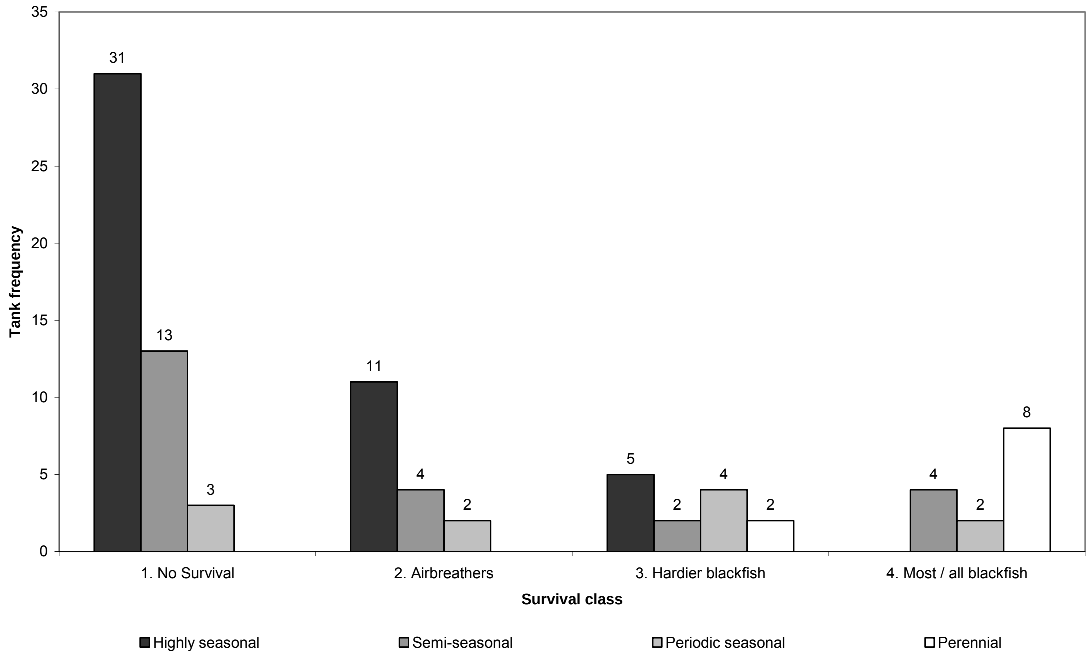
Table 2.9 Classification of tanks according to persistence of blackfish varieties during the main dry season

Class	Species survival	Water storage characteristics
1	No Survival	Tank completely dry
2	Potential for survival of air breathing species	Shallow mud < 20 m^2
3	Potential for survival of air breathing and hardier blackfish	Shallow Muddy pool 20-100 m^2
4	Potential for survival of most or all blackfish species	Pool greater than 100m^2 & 20-30cm deep

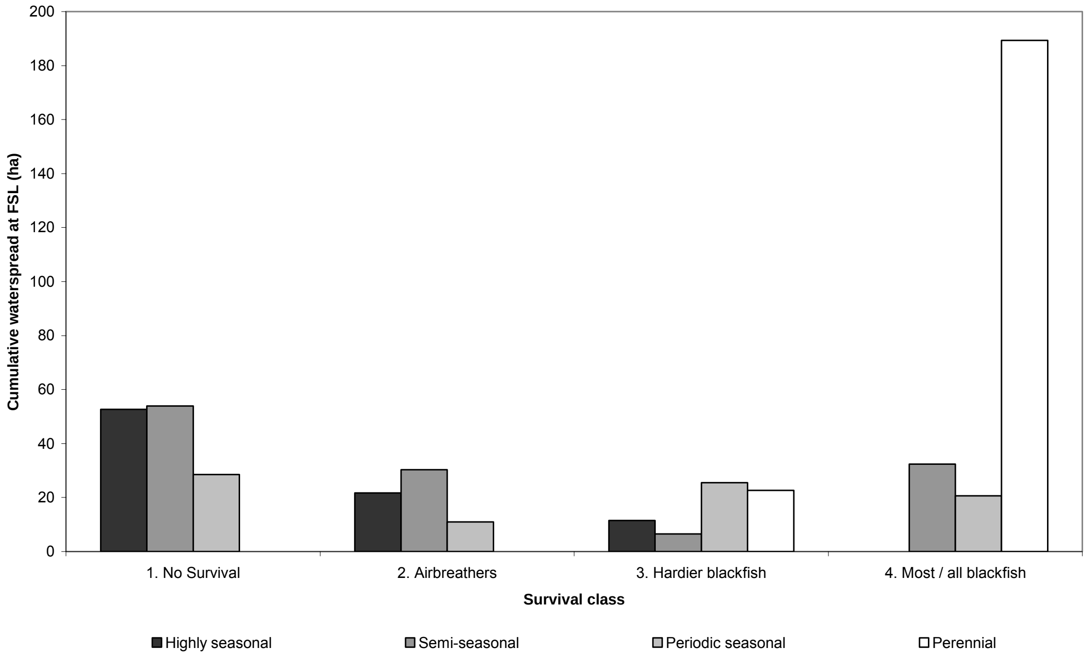
Plate 2.4 Climbing perch (*Anabas testudineus*) an air-breathing 'blackfish' caught in a residual muddy pool, Ankendawewa tank, Giribawa August 2000

Figure 2.16.A shows how survival strategies corresponded with tank seasonality during the dry season of 2000. No survival was possible in 51.7 % of the 91 tanks in the sample (class 1) whilst 18.7% of tanks supported survival of only the hardiest air-breathing varieties (class 2). These classes consisted predominantly of highly and semi-seasonal tanks. The class 1 tanks constitute 26.7% of the total combined water-spread at full supply level and the class 2 tanks 12.4% (Figure 2.16.B). Class 3 and 4 tanks represented 14.3% and15.4% of the total sample frequency respectively and together, 60.9% of total water-spread. Class 3 species occurred across the full spectrum of seasonality, whilst class 4 species were never observed in highly-seasonal tanks.

These results show that without viable migration routes or re-stocking, at least 70% of tanks representing 39% of total FSL water-spread could be expected to yield little or no production over the following season. The following sections consider survey results relating to two key determinants of migration and natural repopulation potential; spill characteristics and surplus weir design. Finally, all findings are combined to produce a baseline map showing the status of fish stocks in the Giribawa cascades prior to the phase 2 interventions.



A



B

Figure 2.16 A and B: Graphs showing (A) frequency of tanks (B) cumulative water-spread area (at FSL) of tanks, grouped by fish survival strategy (see Table 2.9) and tank seasonality; Giribawa and Anamaduwa research areas, Jul - Sep 2000

2.3.6 Spill periodicity, duration and synchrony

Detailed information on the timing and duration of spill events were collected from key informants and by direct observation during four cultivation seasons; *maha* 1999/00 to *yala* 2001 inclusive (Table 2.10). Spill frequencies were extremely low during the first two seasons. Only 1.5% (1 tank) of tanks in Giribawa and 16% (4 tanks) in Anamaduwa spilled. These ranged from highly seasonal to perennial. The events were moderate in size and duration lasting from one to five days during April.

Table 2.10 Frequency and duration of spill events in Anamaduwa and Giribawa research areas, *maha* 1999 to *yala* 2001. Ratios show the number of tanks spilling against the total number of tanks sampled in each seasonal class (source: key informants[1] and field observation[2])

Season	*Maha* 99/00[1]		*Yala* 00[1]		*Maha* 00/01[1]		*Yala* 01[2]	
Research Area[3]	**ANM**	**GBW**	**ANM**	**GBW**	**ANM[4]**	**GBW[5]**	**ANM**	**GBW**
Total tanks (n)	24	68	24	68	NC	69	18	72
Highly seasonal	0:8	1:39	1:8	0:39	NC	5:39	3:6	36:37
Semi-seasonal	0:9	0:14	0:9	0:14	NC	1:14	2:6	16:17
Periodic-seasonal	0:5	0:6	1:5	0:6	NC	1:7	1:4	8:8
Perennial	1:2	0:9	1:2	0:9	NC	1:9	1:2	10:10
% tanks spilling	3.5	1.5	16	0	NC	11.6	38.9	97.2
Month	Feb	Feb	Apr	NA	NC	Jan – Mar	Apr - May	Apr – May
Duration (days)	7	3-4	1-7	NA	NC	1-7	2-11	2-30
Mean duration	7	3.5	2.9	NA	NC	3.2	6.6	9.5

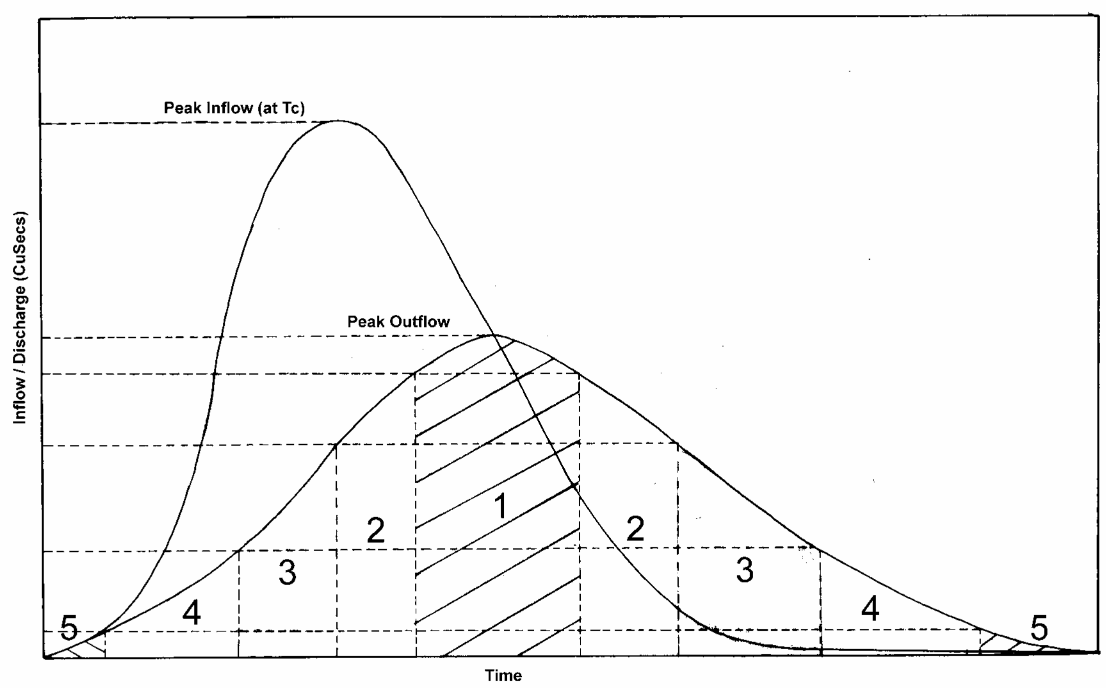
[3]ANM = Anamaduwa, GBW = Giribawa [4]Anamaduwa spill events not assessed during *maha* 00/01
[5]Giribawa *maha* 00/01 spills events are shown in Figure 2.22

Levels were much higher in the second year, despite the inversion of the SW and NE monsoons (section 2.3.2). This resulted in a higher frequency of spill events during the *yala* season; nearly all the tanks in the Giribawa sample (97%) spilled during the *yala* season and 39% in Anamaduwa. During the 99/00 *maha* season cultivation took place under only four tanks in the complete survey, therefore in the remaining cases irrigation management could be excluded as a water-balance variable, i.e. spill events were purely a consequence of climatic and tank hydrological characteristics. The four cultivated tanks (highly seasonal and semi-seasonal) were excluded from the remaining analysis as was Maha Madawalagame with its breached bund (section 2.3.3.1).

Where the irrigation department design criteria are adhered to, surplus inflows and therefore spill events should occur with an average frequency of almost three out of every four *maha* seasons. Over the research period of four years, major events when almost all tanks spilled, were recorded in both research areas during the *maha* seasons of 1998/99 and 2002/03 (after the phase 2 trials) and to a lesser extent, during the *yala* 2001 season in the Giribawa area. Although the timeframe is relatively short, it does suggest that in this respect most tanks are operating within design criteria.

This relative timing of spill events in different tanks within the same watershed also has implications for crop cultivation and fish migration. Again, where design criteria are met, operational tanks within a single cascade should commence spilling more or less simultaneously though lower tanks can be expected to spill longer as result of the extended concentration time (see Figure 2.17) for receipt of ground water inflows from their gross catchment inclusive of any superior tanks. Synchronous spills mean that lower tanks are unlikely to benefit from additional spill inflows, i.e. as tanks fill and spill simultaneously surplus water will be discharged from the bottom of the cascade. Consequently, while gross catchment areas are used for surplus weir design, net catchment areas are used for yield design calculations. There is however, an additional storage allowance for drainage inflows equivalent to 20% of the irrigation supply to the command of the immediately superior tank (Ponrajah 1984).

The timing of migration for different sized cohorts of fish is likely to correspond with spill intensity; smaller fish are more likely to move on the rising and descending leg of the spill outflow hydrograph, while larger fish will move closer to its apex (Figure 2.17). Therefore spill events which are synchronous in timing and intensity, will, in theory, provide continuous routes from lower to upper-watershed areas and thereby optimise potential fish migration. In practice however, larger perennial tanks are more likely to benefit from costly de-silting works (section 2.3.3.1) and in such cases will spill later than smaller tanks in upper-watershed areas. The degree of overlap will then depend on the extent of such works relative to rainfall level and intensity. Here we are principally interested in upstream migration, i.e. movements that will result in repopulation of seasonal tanks in upper watersheds. A sequence of discontinuous spill events in which upper tanks spill first, will have more adverse consequences for upstream migration than the reverse situation of lower tanks spilling first, i.e. connections to upper-watershed tanks may have been terminated before stocks from lower perennial tanks have had the opportunity to move to intermediate nodal axial tanks.



Fish migration potentials

1 High flow rates associated with storms with low return periods (Tr) prevent upstream migration and result in some downstream 'washout' of fish.
2 Larger fish are capable of migrating upstream.
3 Larger and smaller fish are capable of migrating upstream.
4 Sufficient flow only for smaller fish to migrate upstream.
5 Residual flow too low for any fish movement

Where

Tc = Concentration time, i.e. the time for water falling on remotest part of catchment to reach the tank storage area.

Assumptions

- **Tank is at FSL at the start of the storm.**
- **Storm falls on the whole of the catchment simultaneously (this is the typical situation for the smaller catchments of village tanks).**
- **The storm is of uniform intensity over its entire duration.**
- **Storm duration (Td) is less than or equal to Tc (when Tc > Td, the inflow and discharge curves will become trapezoidal).**

Figure 2.17 Simulated flood inflow and outflow hydrographs for a small village tank (after Ponrajah 1994) showing corresponding fish migration potentials

Clearly, in addition to these theoretical hydrological potentials, a range of other environmental behavioural cues will also determine how fish of certain size and species can and will move; this is an area requiring further research. Limited sampling in this study suggested that juvenile tilapias favoured lower flow rates than most other varieties of migrating fish in the same size range. A range of local varieties, especially: *Puntius* spp. *Rasbora* spp. *Mystus* spp. and the exotic snakeskin gouramy (*T. pectoralis*), were observed migrating in large numbers during the relatively sustained and stronger spill-flows more common under lower watershed axial tanks. By contrast, more modest numbers of juvenile tilapias were observed moving in the weaker flows between upper watershed tanks, but were almost entirely absent from the lower watershed samples (Plate 2.5 A, B and C).

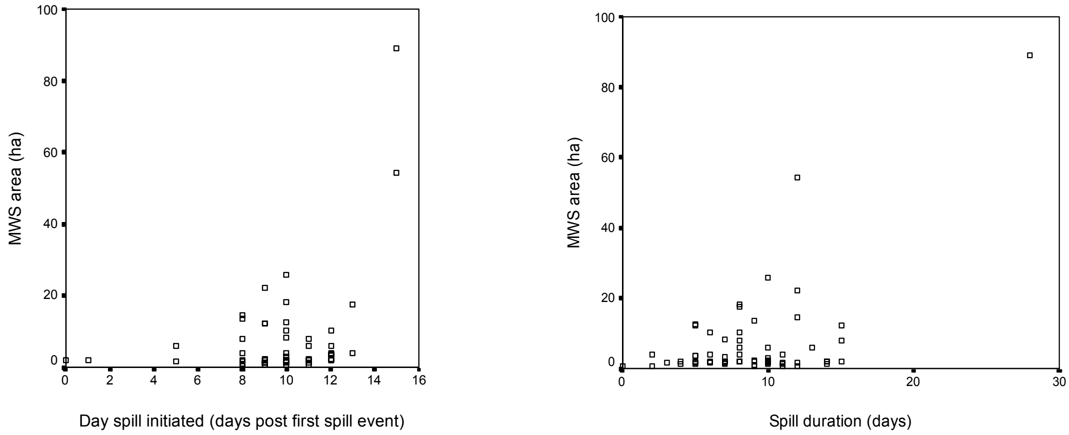
A **B**

C

Plate 2.5 A, B and C -Hand-net samples of migrating fish assembling below tank surplus weirs during April 2001 spill-events in the Giribawa area: (A) Pahala Giribawa – axial 3 / lower watershed (B) Ankendawewa – axial 2 / mid-watershed (C) Kollobendapuwewa – radial / upper watershed.

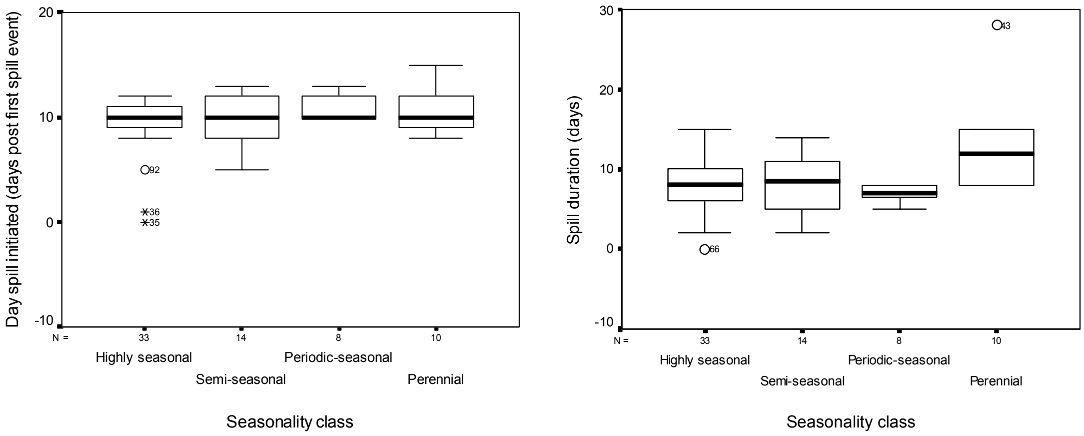
The *yala* 2001 spill events during phase 2 trials occurred in all 91 tanks in the Giribawa sample, albeit at very low flow rates in many instances (i.e. migration potentials 4-5 in Figure 2.17). Figures 2.18 to Figures 2.20 show the timing and duration of these events in 45 of these tanks that were closely monitored. These tanks were all located in the nine adjacent watersheds in the Giribawa area. There was a gap of 15 days between the onset of spill events in the very smallest (first) and largest (last) tanks, though 78% of tanks began spilling within 4 days of each other (Figures 2.18.A). The duration of events ranged from 2 to 30 days with 75% of tanks spilling for between 5 to 12 days (Figures 2.18.B). As anticipated, the largest perennial / axial 4 tanks continued to spill for the longest period as ground water continued to percolate down the cascades after surface flows had ceased (Figures 2.20.B). Although flows were not high enough to stimulate the mass migration of fish observed during the 1998/99 *maha* season, results here indicate that in these cascades at least, the synchronisation of spill events would be very favourable to migration in all but a few of the most highly seasonal tanks.

The combination of spill events and inundation of littoral areas observed in *yala 01* also corresponded with a rise in fish breeding activity. The first evidence was a sudden appearance of snakehead nests or *petav polas* in littoral areas (Chapter 6, Plates 5.8A). This was followed by a marked rise in tilapia nesting and mouth brooding activity observed during test fishing (Chapter 5).



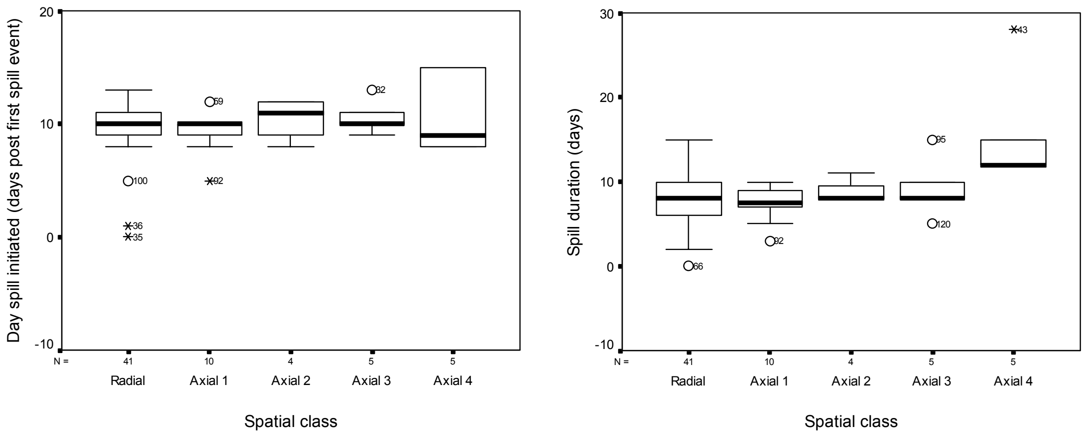
A **B**

Figures 2.18 A and B: Scatter plots of MWS area v spill initiation (A) and spill duration (B) for 91 tanks in the Giribawa research area, Apr – May 2001



A **B**

Figures 2.19 A and B: Box plots of seasonality class v spill initiation (A) and spill duration (B) for 91 tanks in the Giribawa research area, Apr – May 2001



A **B**

Figures 2.20 A and B: Box plots of spatial class v spill initiation (A) and spill duration (B) for 91 tanks in the Giribawa research area, Apr – May 2001

2.3.6.1 Surplus weir design and migration potentials

Surplus weirs are designed to discharge run-offs from storm events with a determined frequency in order to achieve an acceptably low risk of structural failure such as earthen bund breaching. Frequency probabilities are based on 25-year and 50-year historic data periods for minor and major systems respectively over which outflows of storms of different durations / intensities are calculated and the surplus weir designed for the highest outflow. Bund height is determined by adding to FSL level, the afflux and freeboard, taking wave height and wave ride-up into consideration, and an additional safety margin for freak storm events. Afflux is the temporary elevation of water depth above FSL that occurs during storm events and in the case of minor tank design, is restricted to 1-1.5', i.e. during spill events the standing wave above the surplus weir should rise to no more than this height (Ponrajah 1994). In other words, while yield calculations will determine the height of the surplus weir, its width will also be determined by safety considerations. As will be described below, these measures taken to dissipate the erosive potential of spill events can inadvertently create major impediments to fish migration. Although in most cases the problem could be overcome by simple low-cost modifications, this does not happen as the negative impacts on aquatic production potential are never considered during the design process.

Plates showing the range of surplus weir designs found in the two research areas are presented in Appendix 12 and summarised in diagrammatic form in Figure 2.21. The simplest traditional designs were earthen structures requiring regular maintenance. These came to be replaced with permanent stone and latterly concrete structures. Installations appear to have taken place in progressively smaller structures, over the previous 10-20 years in the case of many radial tanks in the current survey. Only two of the 120 survey tanks retained earthen surplus weirs. One of these, Karambawewa (KRB), is shown protected by sandbags during a spill event in Appendix 12 (Plate A12.A).

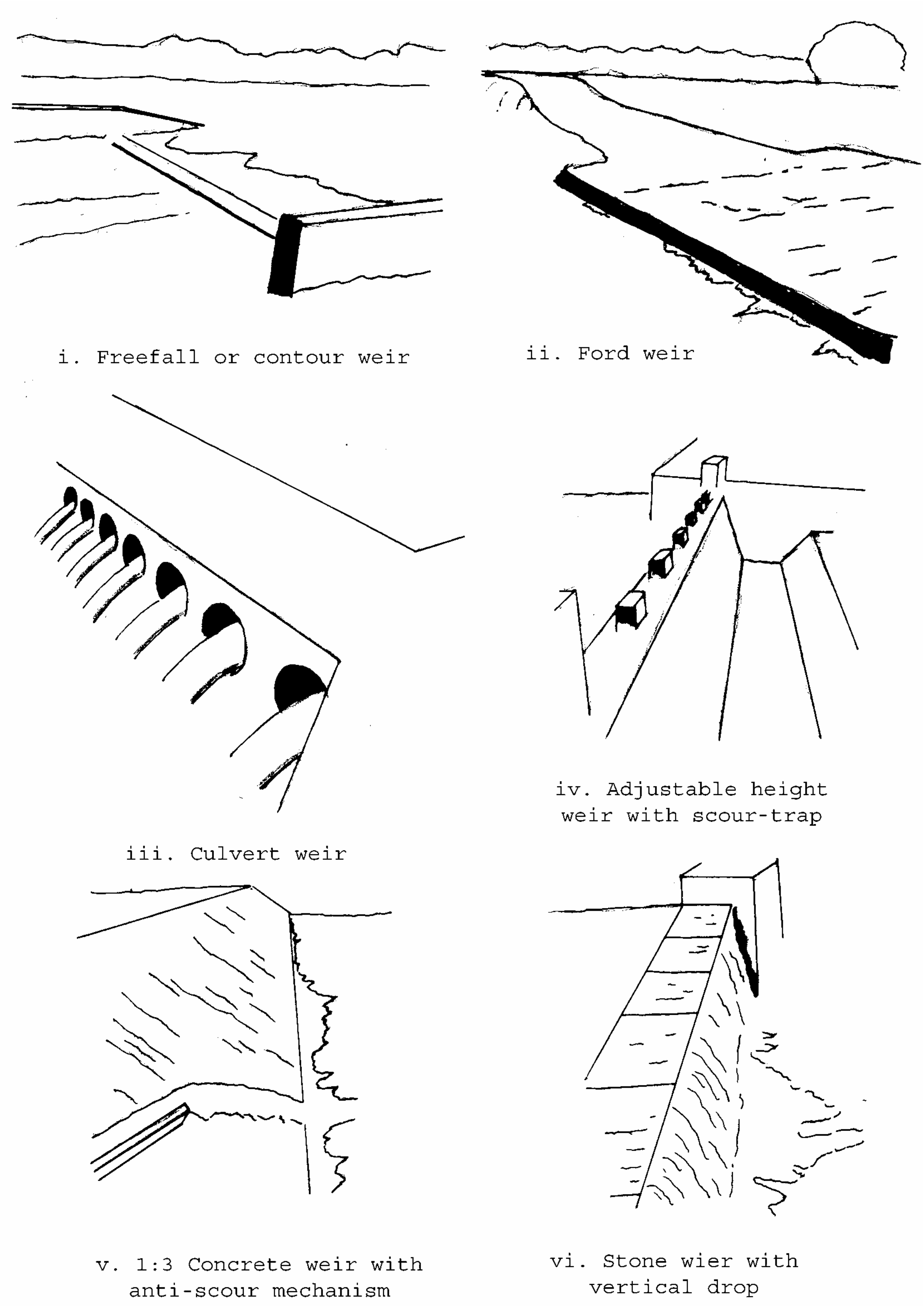


Figure 2.21 Surplus weir designs in the Giribawa research area, listed in order of occurrence from upper to lower-watershed areas (see Appendix 12)

The most ‘migration friendly’ spillways are ‘freefall’ or contour systems which have no requirement for a weir. These result from extending one or both ends of the earthen bund at a shallow angle to the FSL contour line, so as to ultimately dissipate surplus water while avoiding any erosive vertical fall. Figure 2.21-i shows a concrete scour plate and sidewalls installed at the end of a freefall bund. In other instances where there was heavy traffic on the bund, these plates were extended in width to form concrete fords.

In the Deccan and Chotanagpur plateau areas of India, tanks were traditionally connected along shallow contour lines using freefall spillways in order to avoid the cost and / or the technical difficulties associated with the construction of surplus weirs (Dhan Foundation 2004). Their use however, is restricted to smaller tanks in suitably undulating terrain. In this study, they were limited to several radial tanks including one other intervention tank, Serugaswewa (SER). In the latter instance, the installation necessitated the construction of an extended bund (Appendix 20: Fig. A20.2) which may have mitigated any cost benefit.

As the vertical height and width of engineered weirs progressively increases in proportion to tank size, so the impediment they constitute to fish migration is also likely to become greater with movement down the cascade. Some of the older stone weirs with vertical drops present the most insurmountable obstacles. Larger modern concrete weirs often incorporate a downstream slope to provide structural support. Given adequate flow conditions, larger fish may be able to swim up such slopes that are built on a 1:3 gradient in higher weirs.

The incorporation of anti-scour devices in these structures can also assist upstream migration. For example, ‘scour-traps’ constructed below the weir act as a partial ladder, reducing the effective vertical height (Figure 2.21-iv.). In one instance, an anti-scour plate that had been installed on the face of the weir to prevent damage to the sidewall was acting as an extremely efficient channel for fish to navigate, although the weir was over 2.5m in vertical height (Figure 2.21-v.). This feature was exploited by local youth who were observed trapping a wide range of fish sizes and varieties including tilapia and indigenous small cyprinids using hand nets.

One other relatively common structure on intermediate size tanks was the culvert weir. These consisted of one or more concrete drainage pipes running in parallel through the bund. The relative merits and disadvantages of these structures for migration of fish were more difficult to gauge. Again, much depends on the height of the vertical drop below the culvert. However, their tubular structure will also increase the afflux height by channelling water. This 'channelling' could initiate upstream migration at lower flow rates relative to a conventional 'flat' weir of comparable width while potentially washing fish down at higher rates. The channel flow also facilitates a very simple adaptation used by farmers at a number of sites. This simply involved placement of a curved sheet leading down from the culvert which dramatically improved the passage of fish (Appendix 12: Plate A12.F).

Some tanks have spillways at each end of the bund, which usually then merge into a single channel below the command area. This is mainly a feature of larger perennial tanks. Such paired weirs will typically be constructed at the same elevation, though they may differ in terms of their downstream height depending on terrain. The provision of two spillways might also enhance migration potential were one to become obstructed.

Finally, weirs were classified into two groups based on observation of spill events; those that offered some potential for migration and those which were clearly impassable. The latter category included stone weirs with vertical drops greater than 1.75m and sloping concrete weirs with a vertical elevation greater than 2m (allowing for the positive effects of scour devices described above). These findings were used in the baseline assessment of standing stocks discussed in the next section.

2.3.7 Baseline assessment of standing stocks in Giribawa STCs

Based on the fish survival and spill design characteristics described in the previous sections, it was possible to plot a watershed map showing the likely status of fish stocks in the Giribawa tanks immediately prior to the second phase of action research that commenced in November 2000 (Figure 2.22). Of a total 87 tanks, 34 fell into the 'survival-class 1' category as they dried during the 2000 dry season with no potential for fish survival. These were mostly small radial tanks under 1ha MWS. During the following *maha* season, only seven spill events were recorded. These linked twelve tanks, though one of these routes was rendered impassable to fish migrating upstream by a 2m high vertical stone weir. The net result was that 33 tanks in the sample began 2001 devoid of natural stocks, 20 tanks commenced with only residual black fish stocks (class 2), 13 fell into the class 3 category, while 22 were either perennial or had spill-linkages with perennial tanks with no barriers to migration. In other words, over half the tanks in the survey had negligible capacity for natural fish production at the start of 2001. Similar low rainfall patterns during the previous two years meant that this pattern of low production was likely to have persisted for three years.

The comprehensive spill events of April 2001 probably resulted in repopulation of many tanks. However, the frequency and duration of these events was relatively low and the intensity of fish movement was much lower than that observed during the last major *maha* spill events in 1998 (section 2.3.6). On this occasion, several weeks of persistent and intense rainfall triggered a mass movement of juvenile fish upstream. As spillways overflowed their normal channels fish were observed moving over wide areas in the resulting sheet-flows. Ambulatory air-breathers including snakehead and climbing perch are capable of the most extensive migration under such marginal conditions, though substantial numbers of juvenile tilapia were also seen moving upstream in extremely shallow rivulets.

The condition of spill channels was not systematically investigated as part of this survey, not least because many ran through dense patches of scrub jungle. However, it was clear that these routes received little or no regular maintenance, especially in upper-watershed areas and there poor condition was likely to represent an additional impediment to migration.

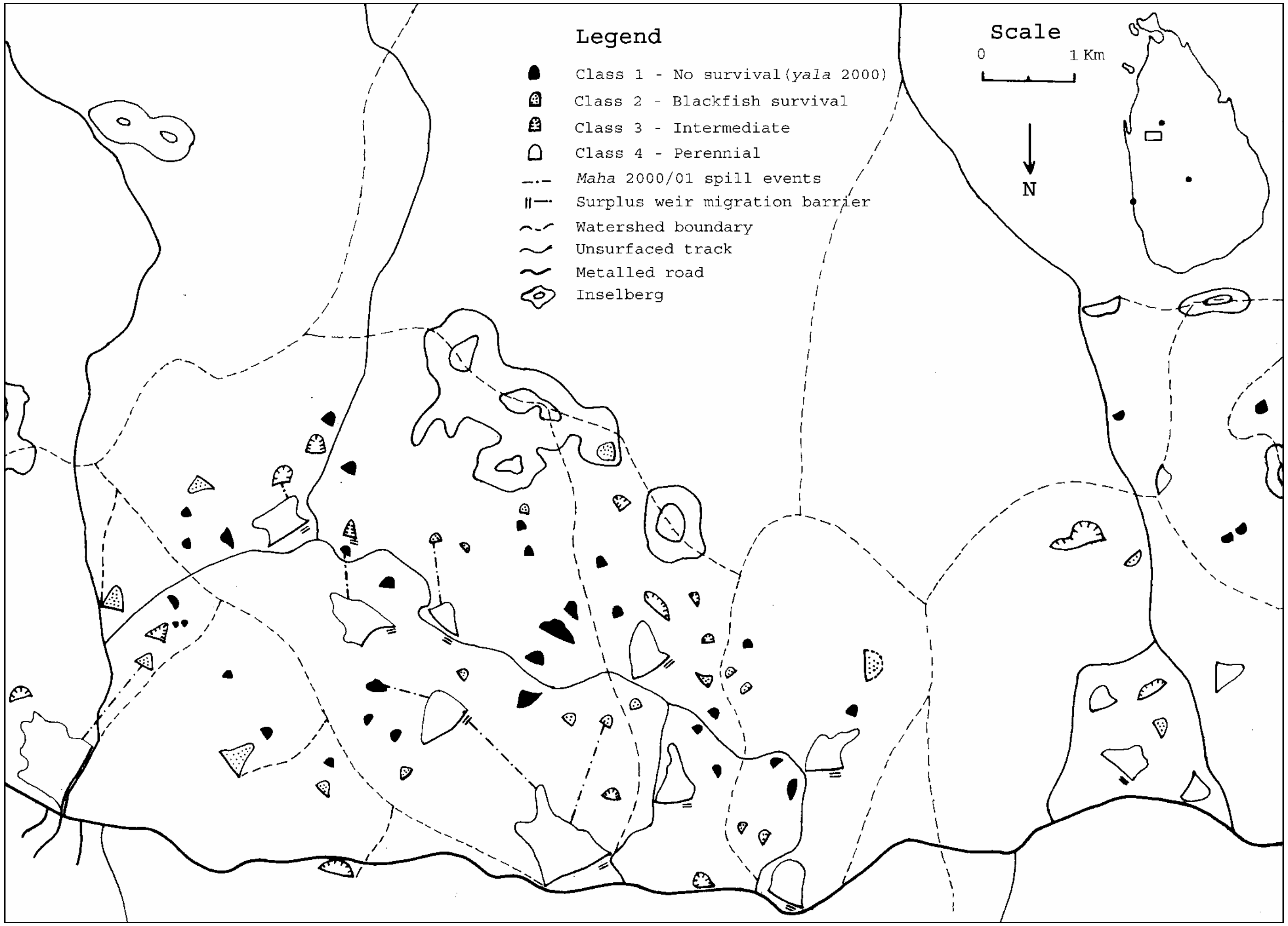


Figure 2.22 Map of Giribawa research area showing tanks classified by fish survival category *yala* 2000 (see Table 2.9) and fish migration potential, *yala* 2001

2.4 Summary

Village tanks are hydrologically interconnected storage and regulating reservoirs that serve multiple livelihood functions. In ranking exercises, farmers prioritised subsistence fisheries below bathing and irrigation. Although many complementarities exist between these and other functions, negative externalities imposed by fishing on the two priority uses also has potential to cause intra and inter-community conflicts. Poor understanding of this reality has been a contributory factor in the past failure of culture-based stocking interventions (Chapter 5).

Only slightly more than half the tanks surveyed in the two research areas were marked on the most recent survey maps. In terms of the aquatic production typologies devised here, nearly all fell into highly / semi-seasonal categories, or a radial or axial 1 spatial category. Most were under 2ha at MWS and suffer complete loss of fish stocks at least once every five years.

Cultivation frequency under many seasonal tanks was lower than could be expected given that rainfall levels over the research period were consistent with longer-term trends upon which tank design criteria are based. This corresponds with increased availability of alternative livelihood opportunities under nearby major irrigation schemes, in place of higher risk and lower yielding cultivation under seasonal tanks.

Seasonality and spill frequency are identified as the main hydrologic factors limiting natural fish production. Results of the watershed hydrological analysis indicate that tanks in the longer settled Anamaduwa area were more likely to be over-developed in relation to their available catchment area. Tank rehabilitation that is not coordinated at the cascade level will move water deficits downstream while reducing spill-frequency and therefore potential for natural repopulation of seasonal tanks.

Our results showed that after three successive low rainfall years over half the tanks in the Giribawa survey had negligible capacity for natural fish production at the start of 2001, when our phase 2 stocking interventions commenced. Taken together, the results suggest that sub-optimal production levels can be expected in three out of four years. Key informant accounts of periodic ‘windfall’ harvests interspersed between drought years supported this finding.

These data indicate a substantially under-reported resource of smaller seasonal tanks and that there is a necessity for simple enhancement steps if the potential productivity of this resource is to be unlocked. The results suggest two options; first, modification of weirs, possibly by extending anti-scour systems so they also serve as fish passes. Planners should also be made aware of the need to consider migration during installation. However, such modifications will only bring periodic benefits, i.e. when tanks actually spill. A second avenue and the one adopted for action research in this study, was to investigate the potential for moving locally sourced fish stocks from perennial tanks to seasonal water-bodies in upper-watershed areas (Chapter 5). Such low input stocking enhancements may also represent an alternative production strategy during years when rainfall is too low for farmers to risk supplementary irrigation. This can actually extend the period of residual storage in smaller seasonal tanks.

Accordingly, the focus of research in the remaining chapters resolves to the level of individual communities and their associated tanks. Methods applied at this ‘community level’ are described in Chapter 3. Social characteristics of the communities are described in Chapter 4. Finally the outcomes of two phases of action research based on stocking enhancements in the same communities are presented in Chapters 5 and 6.

Chapter 3 Development of approaches to understanding community

3.1 Strategies for community level research

The remaining research components, undertaken at the village / community level had three main purposes (1) to gain understanding of the pre-existing situation or livelihood context in order to design and locate sites for farmer managed trials in two subsequent phases of action research (Chapter 5), (2) to monitor any positive or negative change that might result from these trials and their impact on different interest groups; in particular those identified as being poor (3) to provide iterative feedback in an adaptive learning process in order to enhance positive impacts and increase likelihood of sustainable adoption.

It was envisaged that the application of a broad range of inter-disciplinary methods, including rapid participatory techniques and more formal structured survey techniques, would, in different ways, contribute to our understanding of the complexities of community interaction. In the analysis presented in this and subsequent chapters, I also consider which methods worked best, where and why. The methods described here relate to outputs presented in Chapters 4 - 6.

3.1.1 Participatory v formal survey techniques

At the outset, i.e. during the preliminary situation analysis, focus was predominantly on the application of participatory techniques, which, since their introduction in the 1980's, have become increasingly popular tools in applied research projects and development programs. Participatory methodologies stress the importance of understanding local priorities and needs above researcher defined notions of success and failure.

'Rapid rural appraisal' (RRA) and 'participatory rural appraisal' (PRA) are terms coined to reflect the degree of emphasis on local participation, which will vary according to the purpose of the work, resource availability and the skill of facilitators. Counter intuitively, RRA is often more resource intensive due to the requirement for a multidisciplinary external team. In PRA, local participants are facilitated to participate in all aspects of the research or development project: formulation of a research / development agenda, collection, analysis and implementation of results etc. RRA is necessarily more consultative and consequently, fosters less sense of local ownership. In this study, emphasis shifted from RRA to PRA as research progressed from the preliminary situational analysis, to action research in a more geographically focused area.

Both PRA and RRA rely to varying degrees on the same constantly evolving participatory toolkit. In both approaches there is a concerted effort to avoid biases by being aware of them and being systematic in taking into account different sets of interests. Consequently, they can provide a complex understanding of processes and the connections between different disciplines, activities and conditions.

Participatory appraisals require careful planning and structure but are much more 'open' and flexible than formal survey methods. By stressing constant review and iteration the focus of research can be more easily redirected where necessary. They are also more time and cost efficient; the maxim of 'appropriate imprecision' is adopted, thereby reducing the likelihood of gathering 'interesting' though non-essential information.

There are also disadvantages to the approach. Firstly 'quick and dirty' methods designed to ensure reasonable coverage will not produce statistically sound results making conclusions less generalisable. Secondly, casual association between facilitators and participants, especially in RRA is unlikely to produce the familiarity or rapport required to achieve a good understanding of local power hierarchies. Such understanding is critical; the common property resource and multiple-use characteristics of village tanks predispose stocking interventions to complex political interactions between multiple stakeholders (Chapter 1).

Mosse (1993) criticises PRA from a more fundamental ethnographic perspective. He points out that they involve public social events which construct local knowledge in ways that are strongly influenced by existing social relationships, especially relations of gender, power and the facilitators themselves. In the current study, such problems were only overcome by longer term association with intervention communities.

Another constraint is associated with the use of 'participatory impact monitoring' (PIM) techniques to assess change brought about by the type of 'extensive' development intervention practiced in this study. When changes are small, cumulative and effects widely distributed, net benefits may still be considerable and their incremental nature may make them more sustainable and less susceptible to appropriation by elites. Furthermore, the low input / output enhancement strategy piloted here was designed to achieve equitable distribution and direct food security through extended harvesting periods (Chapter 5), in contrast to conventional culture-based stocking strategies based on intensive; short-duration 'bulk' harvests.

PIM methods include *a priori* and *a posteri* comparison of resource flow diagrams, ranking and scoring techniques and various simple recall techniques. The accuracy of such methods will depend, amongst other factors, on the interval and frequency of monitoring events together with the level and extent of any impacts. Although recall techniques can provide reasonable insight into changes occurring at the individual household level, or where broader changes are more dramatic and concentrated in a short space of time, they are less useful for detecting the type of low level change over extended periods described above.

Consequently, in the second phase of trials, participatory techniques were complemented with recurrent survey methods designed to gather harder qualitative and quantitative data. RRA results provided the basis for the design of a more structured but highly purposive longitudinal household questionnaire survey (Appendix 24). In order to maintain flexibility, the same survey retained a number of semi-structured elements. Local participants were also recruited to monitor environmental conditions and fish yields in the stocked tanks.

The longitudinal nature of these surveys combined with selection of research sites in adjacent watersheds (Figure 2.6), resulted in much closer association with target communities than had been possible in the phase 1 trials, thereby fostering greater trust and transparency. This enhanced insights into social hierarchies, the operation of social taboos and other norms with consequences for individual and collective action. It also resulted in improved understanding of intra-community relationships with respect to natural resource management and exploitation.

PIM, direct observation and structured questionnaire techniques were applied simultaneously in phase 2 trials. Also, in order to highlight the concurrent agricultural role of the same tanks to livelihoods, at the end of the trials, a survey of cultivation strategies was carried outwith the panel of households who had already participated in the longitudinal survey. The methods used in all these activities are described in greater detail below and their individual strengths, weaknesses and complementarities are discussed in Chapters 5 and 6.

3.1.2 Action research

Action research is a strategy for social research (rather than a specific method) dating back to the late 1940's, which evolved as a means of linking social theory and practice (Denscombe 1999). The strategy clearly pre-empted and influenced many features of the more recent participatory paradigm. This is evident in its four defining characteristics:

- It is aimed at addressing practical real world problems often in organisational settings.
- It is geared to stimulating change as a central component of the research process; both as a means of dealing with problems and as means of discovering more about social phenomena (i.e. rather than viewing change as a separate activity which follows conclusion of the research).
- Research is *cyclical*, i.e. it involves an iterative feedback loop in which initial findings generate possibilities for change which are then implemented and evaluated (in terms of impact and process) as a prelude to further research.
- Those directly affected by the research are encouraged to *participate* as collaborators in its design and implementation rather than being subjects of it.

Action-research strategies lay great stress on practitioner involvement and openness with target groups. While this can result in detailed insider knowledge of how things work, it also increases vulnerability to the ethnographer's problem of reflexivity (i.e. increasing inability to view issues from multiple perspectives rather than an entrenched web of meanings). There is also the problem of combining a demanding time bound workload with systematic and rigorous research. These characteristics mean that the scope of investigation for action research is necessarily localised and relatively small-scale. This has lead to further criticism regarding the generalisability of what are essentially case studies. In this study, these problems were addressed by resorting to action research only after completion of a detailed, and in the event extended situational analysis which provided the context and rationale for selection of research sites and trial design (Chapters 2 and 4, Murray 2000-2004).

3.1.3 Adaptive learning and impact monitoring strategies

The adaptive learning approach stresses the idea of development as a dynamic 'process' requiring flexibility based on continuous experiential learning and emphasis on the social context of outcomes. The process is intended to increase knowledge of the effects of both technical and institutional interventions. It is most appropriate when the biophysical and socio-institutional complexity of resource management systems makes it very difficult to predict exact outcomes at the outset (Hoggarth *et al.* 1999b). The approach rests on the tenet that management strategies based on repeated adaptation, through regular monitoring evaluation and feedback of change can help participants to learn about and deal with such uncertainty.

Although elements of the adaptive learning process were applied in both phases of action research, there was greater scope for its application in the second phase, where an emphasis placed on staggered harvesting strategies (Chapter 6) increased potential for intra-trial iteration. Staggered harvesting activity would by itself provide regular insight into the status of standing stocks, on which more informed collective-management decisions might be based. However, without regular forums to pool this information, the overall benefits to the community might be less apparent than the traditional single intensive collective-harvest event, for example. Therefore, in order to increase the likelihood of the sustainable adoption of these extensive production systems, a more formal strategy would be required to ensure promotion of awareness to both participants and non-participants (section 3.7).

3.2 Research methods

A flow diagram showing the overall research design is shown in Figure 1.1 and a timetable of individual components in Table 1.4 (Chapter 1). The process began with a preparatory situational analysis including market studies, cascade typologies, preliminary village PRA exercises etc. Outcomes are discussed in Chapters 1, 2, 4 and other relevant points in the text. This phase also incorporated a secondary stakeholder workshop, followed by series of primary stakeholder workshops held in villages identified during the preliminary screening process outlined in Chapter 1. These sources provided the basis for formulation of a research agenda and sites for the two consecutive phases of action research during 2000 and 2001. Phase 2 sites were selected and methods modified based on the outcome of the phase 1 pilot trials.

All the trials took place in traditional '*purana*' villages (Chapter 4), selected on the basis of wealth characteristics, access to suitable water resources and willingness of the community to participate in the research. Phase 1 trials were carried out in five tanks belonging to three communities in the separate Giribawa / Anamaduwa research areas and phase 2 trials in five tanks belonging to four adjacent communities in the Giribawa area (Chapter 5; section 5.5.1). Gurulupitigama (GUR), a larger low-caste village which alone of all the trial tanks was located in a lower-watershed position, was also included in the second phase as a non-stocked control for watershed position. Only one tank SER, which demonstrated good technical potential, was stocked in both trial phases, but monitored less intensively in the second phase. Further details of site selection and the methodological iteration between the two trial phases are presented in Chapter 5.

To assess social and technical change resulting from the trials our approach involved an array of horizontal (baseline) and longitudinal, systematic and semi-structured components. These combined direct observational, key informant and individual household data sources.

Baseline activities which encompassed all households in each intervention community included: (1) wealth ranking and social mapping – section 3.3.1 (2) a baseline livelihood survey – section 3.4.3 (3) a baseline intervention tank survey – section 3.4.2. Results from these activities were subsequently used in the design of stratified monitoring and evaluation surveys.

Action-research monitoring designs incorporated four longitudinal (1, 2, 4 and 5) and two horizontal components (3 and 6):

(1) Direct observation of staggered fishing activity – section 3.5.1

(2) Key informant reports on staggered fishing activity – section 3.5.1

(3) Direct observation of collective fishing activity – section 3.5.2

(4) Periodic test fishing – section 3.5.3

(5) A semi-structured wealth stratified household survey – section 3.6

(6) A wealth stratified participatory impact monitoring (PIM) survey carried out upon completion of the trials – section 3.8

As noted earlier, the most substantive difference between the two trial phases monitoring effort, was a change of emphasis from intensive 'collective' harvesting in the first to low-level recurrent 'staggered' harvesting in the second. Consequently, only one activity (3) was applied in phase 1 trials whereas the remaining longitudinal components were devised for phase 2. The PIM survey (6) was also devised and applied only in the second phase.

In three phase 2 intervention communities (excluding GUR and SER), results of these surveys along with outcomes of (7) the water management survey (Murray 2004b, Appendix 16 - Appendix 23), were presented at the end of monthly Death Donation Society (DDS - Chapter 4) meetings on a total of four occasions. Research staff also expanded the feedback component by sharing results between neighbouring participant communities.

One specific group of PRA techniques; ranking and scoring, were applied recurrently at various stages of the research (section 3.3). They are particularly useful at the community level, as a quantitative means of assessing the priorities of different interest groups. The wealth ranking referred to above is a more specialised application which provides a basis for the stratified design of other survey methods.

The multi-disciplinary nature of the work and the need to operate multiple longitudinal surveys also presented formidable data management and cross-referencing difficulties. Rarely are such problems explicitly addressed, although they frequently result in the curtailment of data gathering activity or the even more wasteful discarding of data. Consequently, a considerable time investment was made in the design of a relational data-base system in which results of all but the intervention water quality / hydrology surveys were recorded (Appendix 37). The advantages and limitations of this approach are discussed in section 3.11.

A checklist of the methods described above together with the various other research activities undertaken concurrently, in or around a total of ten different village tanks, (nine stocked during two phases of action research) is shown in Table 3.1.

Table 3.1 Summary of research activities around ten village tanks in seven villages of the Giribawa and Anamaduwa research areas, 2000-2002.

Research components	Thesis Chapter(s)	Research area [1]/ *Village* / **Tank** [2]								
		AND	GIR							
		ULP	*MAD*		*IMK*		*LHG*	*GBW*	*GUR*	*PGB*
		KRG^{t} / ULP^{t}	**KBW^{t}**	**LUN^{t}**	**SER^{t}**	**IMK^{t}**	**LHG^{t}**	**GBW^{t}**	**GUR^{t}**	**PGB^{3t}**
1. Hydrological / topographic										
(i) Rainfall	2			x		x	x	x	x	
(ii) Depth	*		x	x	x	x	x	x	x	x
(iii) Topographic survey			x	x	x	x	x	x		
(iv) Planimetric area			x	x	x	x	x	x	x	x
(v) Irrigation survey			x	x	x		x	x		
2. Water quality / nutrients			x	x	x	x	x	x	x	x
3. Livestock movement			x	x	x	x	x	x	x	x
4. Phase 1 Intervention	5,6	x			x	x			x	
5. Phase 2 Intervention	5,5		x	x	x		x	x		
6. Wealth ranking	3,4,5,6	x	x	x	x	x	x	x	x	
7. Household monitoring baseline	3,4,6			x		x	x	x		
8. Household monitoring longitudinal	3,4,6		x	x		x	x	x	x	
9. Farming strategies	3,4		x	x		x	x	x	x	
10. Irrigation strategies	*		x			x	x	x	x	
11. Test fishing	3,5		x	x	x		x	x		
12. Participant feedback meetings	3,5,6	x	x	x			x	x		
13. Participatory impact monitoring	3,6		x	x			x	x		

[1]Research Area: AND = Anamaduwa, GIR = Giribawa

[2]Village / tank names: ULP^{t} = Ulpathwewa, KRG^{t} = Keeriyagahawewa, KBW^{t} = Karambawewa, LUN^{t} = Lunawewa, SER^{t} = Serugaswewa, IMK^{t} = Ihala Maradankadawala, LHG^{t} = Lokahettiyagama, GBW^{t} = Galenbindunewewa, GUR^{t} = Gurulupitigama, PGB^{t} = Pahala Giribawa.

[3]Largest rainfed tank in the survey and source of wild seed in the phase 2 trials.

* Reported in Murray (2004b) and Appendix 16 - Appendix 23

3.2.1 Stakeholder analysis and formulation of a participatory research agenda.

When researching any new development initiative it is necessary to assess how all the people that might be involved are likely to be affected. In *stakeholder analysis*, an attempt is made to understand the potential interactions, conflicts and trade-offs associated with a particular course of action (World Bank 2003). Stakeholder analysis can also be an important first step in developing a shared idea of the work to be done and how to go about it: to clarify differences in contribution, expectations and priorities, and to negotiate acceptance of these. In this study, stakeholder analysis was undertaken to determine participants' priorities for the formulation of a research agenda for in-depth study of aquaculture potential in small-scale irrigation systems within their geographic and socio-economic context.

As individuals, groups, communities and institutions, 'stakeholders' are present at various levels. *Primary stakeholders* tend to live in close proximity to the research location and are likely to be directly affected by the research outcomes. Further removed are *secondary stakeholders* who have an interest in the resources affected by the research strategies, or are involved in the delivery or decision-making processes associated with research activities. Within this second group are those who affect and are also most affected by change, though unforeseen losses more often impact most seriously on the poorest primary stakeholders.

As it proved impracticable to bring primary and secondary stakeholders together within a single forum (due to language difficulties, incompatible settings etc.), a single secondary stakeholder workshop was followed by multiple primary stakeholders meetings within village settings.

3.2.1.1 Secondary stakeholder workshops

Attending this 2-day workshop held in the hill capital, Kandy, were over 30 participants from local and central government agencies, NGO's, donors, banks and research organisations (IoA 1999). The workshop activities culminated in the formation of a preliminary research agenda. To promote discussion, stakeholders were arranged into three institutional groups (research, governmental and NGO) along with one all female group, and invited to identify knowledge gaps and researchable constraints to aquaculture within four categories; technical, institutional, socio-economic and biological. Results are summarised in Chapter 5 and Appendix 32.

3.2.1.2 Primary stakeholder workshops

During the initial situational phase of research in 1999, meetings were held in 11 of the 24 *purana* villages incorporated in the watershed analysis of Anamaduwa and Giribawa research areas (Plates 3.1 A and B). These locations represented a range of caste and watershed settings and were perceived as having potential for aquaculture according to our preliminary research hypotheses. Attendance at meetings convened expressly for the project purpose proved highly unpredictable; one of the reasons for this was that PRA exercises had been undertaken in several of the intervention villages as components of earlier development programs, resulting in a degree of PRA fatigue. Consequently, where possible, brief (<30 minutes) sessions were incorporated into regular meetings of the most active and broadly inclusive village institutions (i.e. DDS and other village welfare societies – see Chapter 4: section 4.3.10). A range of PRA exercises were tested and adapted as the process progressed:

i. Attendance audit: The dangers of reducing 'community' to an idealised cohesive homogeneous unit were discussed in Chapter 1. Such bias is inherent in many PRA exercises which are scaled up to the community level, e.g. stakeholder workshops and other group exercises. Results are frequently presented as the outcome of a 'community consultation' with no attempt to understand how different groups within the community were actually represented. The following 'social audit' system was conceived as an attempt to redress such problems.

Early in the session while other preliminary activities were taking place, a list detailing the age, sex, primary occupation and literacy of participants was compiled by a member of the research team with the help of key informants. Where possible this was undertaken with the assistance of relevant institutional officials; for example, attendance lists for all DDS meetings are maintained by the society secretary for subscription purposes. The audits were then reviewed by local welfare (*Samurdhi*) animators, permitting us to make some assessment of how representative the meetings were of the wider community. The process was further developed in subsequent community meetings in intervention villages. Detailed wealth ranking and social mapping, undertaken as base-line activities in these cases (section 3.3.1), permitted more exacting assessments.

Auditing also provided the basis for stratification of participants into different interest groups for group PRA activities. Groups were based primarily on occupation characteristics, e.g. irrigators, off-farm labourers, livestock owners and craftsmen, while any participant involved in regular fishing activity or marketing were placed in a separate group regardless of their primary occupation. All females and occasionally older participants (>50 years) were also formed into single groups. These groupings made it possible to look for sources of intra-community consensus and disagreement as well as ensuring that less dominant individuals, including most women, were more likely to participate.

ii. *Fish brain storm:* In open session, participants used an I.D. chart to list the varieties of fish and other aquatic products occurring in their village tanks and any uses to which they were put. The following topics were also investigated: knowledge of fish ecology (population trends and feeding characteristics) and details of any previous community participation in stocking interventions. Results are presented in Chapter 5.

iii. *Watershed maps:* Groups were asked to map the water resources belonging to their own and neighbouring communities; providing insights into inter-community relations and local knowledge of watershed issues. These maps were combined with ordinance survey and field visit information to produce the watershed maps already presented in Chapter 2.

iv. *Fishing mobility maps:* Those identified as being regularly involved in fishing activity were asked to produce mobility maps, giving details (frequency, participant numbers and locations) of the tanks in and around their village that they regularly exploited. Preliminary findings indicated that those involved in regular fishing activity often participated on a reciprocal basis with friends and associates in neighbouring villages. They were also asked to comment on these relationships and sources of external participation in their own villages.

v. *Livestock distribution and grazing patterns:* Participants owning livestock were asked to map their seasonal grazing patterns along with those of any neighbouring communities exploiting pastures around the host community's tanks. Respondents were asked to estimate the numbers and varieties (cattle, water buffalo and goats) corresponding with three seasonal windows; during periods of (1) upland and (2) irrigated cultivation and during (3) the post-cultivation months of dry season.

Because of the limited number of persons involved in livestock rearing and regular fishing activity, difficulties were experienced incorporating the previous two exercises into group sessions. In the case of fishing this was compounded by the low social status accorded to 'regular' subsistence fishing. Consequently, interesting leads were followed up with individual or small group key informant interviews and mapping activities; usually at the respondent's home.

vi. Needs analysis: In order to understand how aquaculture might be adapted to peoples livelihood requirements, basic needs-analyses were conducted in seven of the villages (section 3.2.1.2). Such participatory assessments aimed at eliciting the basic needs of target communities are precursors of most development programmes. To avoid bias resulting from the generation of unreasonable expectation, participants were clearly informed at the outset that the purpose of the exercise was to gain new knowledge with a view to strengthening future development strategies that might benefit the wider community. The exercise was incorporated in a session which combined a range other PRA activities. The needs analysis exercise was itself adapted from a method used for analysing livelihood trends (Ellis 1999).

Depending on attendance, participants were invited to act individually or in groups of up to 4 persons. Groups were formed according to gender and occupational characteristics based on the attendance audit. While literacy levels were generally high (80-95%), care was taken to ensure that any illiterate (mostly older) participants were assisted by literate partners.

The needs analysis exercise revolved around two carefully structured questions presented in the following order:

1 In what ways have living standards in your community improved over the last ten years?
2 In what ways have living standards in your community deteriorated or failed to improve in the way you envisaged over the last ten years?

The first essentially served as dummy question, but also had triangulation value. The second was designed to elicit basic needs in an indirect manner; focusing participant's attentions on recent trends within a defined period and on collective rather than individual requirements. Respondents were requested to try and identify at least 3 different criteria in each case. These results were collected, a list of all different responses compiled on a board and reviewed in open session. Respondents were then asked to score each of the criteria resulting from question 2; from 0 (no significance) to 10 (most significant).

The degree of consensus between different respondents (groups or individuals) was assessed using Friedman's analysis (section 3.8.5), necessitating conversion of scores to ranks. Only intra-community comparisons were possible using this technique, owing to the variable number and type of criteria elicited by each community. The analysis was first carried out on the entire data set produced for each community, then repeated on separate male and female sub-populations. As there was no female participation at two of the meetings (both specifically convened), the latter analysis was only undertaken in four of the six villages.

Although in some instances, apparently obvious criteria were not cited (i.e. no electricity supply, poor housing), no attempt was made to standardise the process by incorporating an exhaustively inclusive list. Consequently, it was possible to make broad intra-community comparisons on the basis of citation frequency. Results are evaluated in Chapter 4.

vii. Intervention options: Finally, the willingness of participants to participate in stocking trials was assessed. At this stage the use of exotic carps had already been discounted due to the range of marketing and bio-physical constraints outlined in

Chapters 1, 5 and Murray (2004b). Consequently, only options based on locally available self-recruiting species including tilapia were evaluated.

In separate groups, participants were asked identify which tanks might be most suitable for stocking and why, and the optimal varieties and timing of fish introductions. Participants were also invited to comment on the potential for integrated pasture improvements in tank bed and catchment areas designed to enhance both livestock and fish production. Possible constraints to individual participation and the likelihood and nature of conflicts which could potentially arise from such interventions were also discussed.

A

B

Plates 3.1 A and B: Group activities in primary stakeholder workshops, Oct-Nov 1999 (A) Lokahettiyagama (B) Danduwellawe

3.2.1.3 Intervention start-up workshops

In communities where a high potential for intervention and willingness to participate was established, follow-up meetings were arranged to discuss and timetable activities. Topics included potential sources of wild and cultured seeds, institutional arrangements, negotiation of individual management responsibilities, rules relating to access and their enforcement mechanisms. Participants were encouraged to adopt an adaptive learning strategy whereby the rules adopted at the outset would be subject to ongoing review and revision during periodic feed-back meetings (section 3.7) facilitated by research staff.

In phase 1, dedicated workshops were hosted by local farmer organisations (FO). FO and other village officials were asked to promote attendance. In phase 2, more inclusive attendance was achieved by incorporating workshops as part of regular village DDS meetings. All meetings were also promoted by project staff posting flyers and making strategic household visits. Further detail of the site selection process is given in sections 5.5.1 and 5.6.1.

3.3 Ranking and scoring techniques

Ranking and scoring techniques provide a quantitative means of assessing overall levels of agreement and subsequently the relative importance of different criteria to different interest groups within the community. They were applied to several components of the research in order to assess the following issues: (1) fish and fish substitute preferences; marketing survey - Murray 2004a (Plate 3.2), (2) water-use priorities; village PRA - Chapter 2, (3) action-research impact criteria; participatory impact monitoring survey (PIM) - section 3.8, Chapter 6.

Plate 3.2 Pair-wise ranking of inland fish varieties and their substitutes, using pictures cards September 2000

In section 3.8.5, the statistical techniques commonly used to assess such data, Friedman's and Wilcoxon's tests, are contrasted with an alternative non-parametric multi-factorial technique, log-linear analysis. A more general critique of the preference ranking method based on lessons learned during this research is given in Murray (2004a).

A fourth application, wealth ranking differs from personal preference ranking / scoring techniques in that it is (a) undertaken by key informants, i.e. based on their perception of the status of others and (b) it aims to define stakeholder boundaries with respect to overall well-being for the purpose of sampling stratification. This in turn provided the basis for comparative analysis in many other surveys including personal preference ranking and scoring. The wealth ranking method is presented in section 3.3.1 along with its spatial component; social mapping.

3.3.1 Wealth ranking and social mapping

Categorisation of households according to relative socio-economic status is a fundamental tool in the study and practice of development. The purpose of these techniques is two-fold; they can be used to improve the targeting of limited development resources and subsequently provide a means of monitoring change. In this poverty-focused research, wealth ranking became the basis of various stratified sampling designs employed in monitoring the impact of community-managed trials.

The method relies on local perceptions of poverty and wealth to provide a quick, flexible and an increasingly accepted alternative to financial or other externally perceived indicators. The latter, more traditional method is likely to be based on fixed sets of reliably quantifiable variables such as asset ownership, income and expenditure, nutrition, health and educational achievement etc. This is time consuming, costly and prone to recall error, seasonal bias and interviewee sensitivity and expectations. Cross-aggregation of results across dimensions of wealth, e.g. nutrition and income, using weighted indices introduces greater complexity and validity concerns (Adams *et al.* 1997). Most seriously, complex and multi-dimensional context of household wealth may be overlooked during the standardisation of these techniques.

Chambers (1994b) pointedly warns against the temptation to standardise the wealth ranking technique as one of its main strengths is its sensitivity to local circumstances and expertise. In the following section I describe how the method was adapted to the prevailing social conditions in the current study. Major criticisms levelled at the technique, particularly those associated with external validity, are also addressed.

Although there are a range of wealth ranking and associated techniques, most incorporate some or all of the following steps which are discussed in turn below: (1) identification and selection of suitable key informants (2) census of households within the community (3) eliciting wealth ranking indicators and classification criteria (4) ranking of households according to aforementioned indicators and criteria. The same panel of two researchers facilitated the entire wealth ranking process in each village.

1. *Key informants*: Local key informants selected for the census step consisted mainly of those holding responsible institutional positions within the village. They included the *Grama Niladhari* (local authority representative), the *Samurdhi Niyamake* (welfare animator) and executive members of the FO or DDS. These officials, who were mostly resident members of the communities they served, in many cases already held detailed demographic manifests which expedited the process. This was of particular importance in GUR, where the community was more than twice the size of any other (with 119 households). This number approached the threshold size with which the technique could realistically be operated in terms of individual key informant recall. These same key informants along with a number of other randomly selected villagers then undertook the ranking process.

This choice also inevitably introduced a degree of gender, age and wealth bias with implications for data reliability. However, inclusion of *Samurdhi Niyamakes* and DDS officials resulted in the participation of three younger female participants out of a total of 12 key informants; 3 in each of the 4 intervention villages. The choice of mainly 'better-off' key informants was also pragmatic given the additional sensitivity associated with eliciting wealth related data from poorer households. At this early stage in our association with the intervention communities, some respondents also appeared inclined to provide 'desired' answers based on self-interest or a wish to please the interviewer. The problem was addressed using triangulation methods discussed below.

2. *Household census*: Wealth ranking was based on two community inventories. Firstly, key informants were asked to enumerate all the households within the community by the name of the household head, his age and occupation. Other summary details of household demography (household size and composition), ancestral domicile, institutional membership and participation in fishing related activity were collected simultaneously. Where possible, official records held by the institutions described above were triangulated with simple recall data.

Secondly, the same key informants were asked to map each household with reference to tanks, roads, and other important landmarks in each village, and each house was assigned a code corresponding with the list of household heads. Finally, household locations were ground-truthed by researchers. This process ultimately yielded the social maps presented in Appendix 28.

Combining these two techniques helped to increase the validity of the wealth ranking process in the following ways:

- Comprehensive coverage of the entire community was ensured.
- Difficulties identifying households where household heads shared similar names or new households had come into being were more readily resolved.
- Triangulation of wealth ranking results with the direct observation of method of house construction (one of the wealth criteria adopted for ranking).

Results were also more readily integrated with subsequent research activities as follows:

- Locating households participating in a range of other wealth stratified monitoring exercises and meetings.
- Determining which wealth strata were participating in different collective activities, e.g. community meetings, staggered and collective fish harvesting.
- Identifying spatial trends in well-being and fishing-related activity based on proximity to tank resources.

3. *Socio-economic indicators and criteria*: Many PRA and RRA practitioners recommend that separate indicators and criteria should be elicited within each community to ensure the wealth ranking process is as participatory as possible, (Chambers 1994). However, critics of the technique charge that this very sensitivity limits meaningful inter-community and cross-regional comparison thereby reducing generalisability of results. Consequently, in the current study a conscious effort was made to discriminate between indicators in terms of their degree of universality within the local context. In this respect, the extended period of situation analysis (Chapter 1, Appendix 9), incorporating needs analysis, permitted broader exploration of local conditions. This included familiarisation with contemporary societal values and goals, their prioritisation and likely implications for social stratification in rural settings.

Table 3.2 shows the four most frequently cited and universally applicable indicators and their classification criteria. The first related to the ownership of agriculturally productive lands, adjudged in terms of access to assured or supplementary irrigation supplies, i.e. including lands within and out-with the villages. However, this criterion failed to address the wide variability in productivity under village tanks at different watershed levels and the increasing importance of non-agricultural occupations to many households. The second criteria; ‘off farm income sources’ while more widely applicable, in practice suffered from a high degree of overlap between different wealth groups. Attempts to increase exclusivity by introducing different categories of participation, assuming more affluent families were like to participate less frequently, also proved impossible to enumerate in a uniform manner.

The remaining two indicators; improved housing and educational standards, were together the most frequently cited aspirations and a major focus for financial investment by those interviewed. Conversely, indicators relating to basic food security and health were rarely mentioned. These findings are consistent with the direction of the State’s human development policies in the post-independence era; in particular, outstanding achievements in primary health care and education. Whilst mean life expectancy is now comparable with that in developed countries (UNDP 1997), many parents still strive to achieve improved educational and vocational opportunities for their children, in order that they might find more lucrative economic opportunities outside the agricultural sector.

The trend towards home improvement appears to be the legacy of a previous regime’s *Gam Udava* (‘village awakening’) drive to encourage the construction of permanent housing in the late 1980’s (Chapter 4). Ownership of such housing (ideally with concrete floors, brick and plaster walls and tiled roofs) has now become a powerful symbol of achievement in the contemporary value system of rural communities. Today, it is rare not to see some evidence of the accumulation of building materials for this purpose amongst even those households still residing in traditional mud and cadjan (thatch) housing.

Three or four separate indicators are conventionally employed in the wealth ranking process (Townsley 1996). However, because of their broad validity and their concise and exclusive categorisation, only the last two criteria, housing and education, were used in this study.

It was possible to resolve between only two broadly applicable educational criteria based on school leaving age; before or after 13-years of age (Grade 8). Older villagers were less likely to have received formal schooling though comparative equity has been achieved in male and female primary education (UNDP 1998). Consequently, this criterion was applied only to younger household members under 30-years of age. Three housing categories were devised as shown in Table 3.2.

Table 3.2 Wealth ranking indicators and criteria provided by key informants in four low-caste villages

Socio-economic indicators	**Wealth group**			**Villages**
	Better-off (BO)	Medium (M)	Poor (P)	
1.Ownership of irrigated land	>2ac lands with assured irrigation	<2ac lands with assured irrigation	None or under seasonal tank	GUR, LHG
2.Off-farm income sources	Own business, salaried job, remittances	Remittances, seasonal agricultural labour, occasional coolie work	Seasonal agricultural labour, coolie work, illicit NR extraction[1]	GUR, LHG, MAD, GBW
3.Housing condition	*Permanent:* Concrete floor, brick wall, tile or corrugated roof, >3 rooms	*Semi – permanent:* Brick wall but earthen floor or Cadjan roof	*Temporary:* Wood / mud wall construction	GUR, LHG, MAD, GBW
4.Mean school leaving age[2]	>13		<13	GUR, LHG, MAD, GBW

[1] Timber extraction, hunting / poaching, alcohol production
[2] For household members less than 30yrs of age

Participants should also be encouraged to determine the number of wealth groups, within a practical ceiling of four and very occasionally five groups (Townsley 1996). In this case, three groups; better-off (BO), medium (M) and poor (P) were identified in each village, while in MAD and GBW key informants also identified a fourth ‘very poor’ group. However, as only 1-2 households fell within this category, they were subsequently reclassified as ‘poor’ for analytical purposes.

4. *Wealth Ranking*: Next, key informants were asked to assign each household to a wealth group based on the criteria discussed above. Cards with pictorial and graphic representations were placed in front of respondents as a continuous reference. The process was repeated with three informants in each village. The final household ranks were assigned according to majority opinion. In rare cases of extreme divergent opinion (i.e. the same household was assigned better-off and poor status) a rank was not assigned until informants were re-consulted and a consensus reached.

While great care was taken to ensure key informants fully understood and remained mindful of the wealth criteria, it was not possible to determine exactly how they employed them, i.e. the relative importance given to each while they assigned ranks. Consequently, it is difficult to assess content validity (i.e. accuracy of the measure) in wealth ranking. Set against this, in not predetermining socio-economic parameters in advance (as in formal survey techniques), local informants had greater opportunity to differentiate according to their own locally appropriate criteria, intuitively combining multiple dimensions of wealth. The technique therefore achieved high empirical validity (i.e. concerning the measurement outcome), correlating well with results of the more formal longitudinal household monitoring survey (section 3.6). It proved necessary to reclassify only one household (in LHG) from poor to medium wealth status.

The same triangulation process also indicated a high degree of inter-community consistency in the selected indicators and therefore a good basis for comparison. In a comprehensive validation study of the technique in Bangladesh Adams *et al* (*ibid*) also reported achieving a high degree of external validity at an inter-regional level.

Baseline household occupancy levels were also collected for the entire villages during wealth ranking exercises. In order to assess whether there were significant differences between wealth groups, results were assessed by multi-factorial ANOVA (SPSS 12) with ‘village’ and ‘wealth rank’ as independent variables (Appendix 29). Multiple *post-hoc* comparisons using Tukey’s test were then used to determine the loci of any significant outcome.

3.4 Baseline activities

Three surveys were designed to provide a baseline of performance indicators with which to assess the external validity of action-research outcomes. The first relating to collective fishing practices was carried out at watershed level, while the other two were implemented only at action-research sites, i.e. village level. Methods are presented below and results in Chapter 5.

3.4.1 Baseline watershed collective fishing survey

The primary purpose of this exercise was to assess how different groups gain or lose under current collective fishing (CF) management practices and access arrangements. The survey was carried out in ten cascades systems between July and September 2000, i.e. concurrent with the phase 1 trials. These systems consisted of 77 tanks; 25 tanks in four watersheds of the Anamaduwa research area and 52 in 6 watersheds of the Giribawa area (Chapter 2). In each case CF frequency and yield characteristics were enumerated. Other checklist items are shown in Appendix 31. While much useful information regarding CF participation was solicited from key informants, their estimates of collective harvest yield proved highly inconsistent. This was due in part to the informal and erratic nature of many of the events making systematic observation correspondingly difficult. Consequently, key informant findings were also triangulated with data from the direct observation of one collective fishing event using the method described in section 3.5.2. The resulting information was of particular relevance to phase 1 trials focused on collective fishing (Chapter 5).

Baseline information relating to staggered harvesting was much more difficult to collect. This was due to a combination of (1) poor recall associated with the small-scale and temporally dispersed nature of the activity and (2) persistent social taboos on subsistence fishing. Consequently, one of the phase 1 action-research sites was also included as a ‘non-intervention’ control in the phase 2 trials.

During the same survey, a picture of traditional collective management practices was built up from discussion with elder village key informants and secondary data sources. Data was also collected on any indigenous enhancement activities currently being practiced, i.e. low level harvest and transfer of local fry / brood-stocks or environmental modifications which might aid fish migration or survival during the dry season.

3.4.2 Baseline intervention tank production survey

In order to estimate levels of standing stocks prior to stocking in both trial phases, the hydrological history of our intervention tanks was obtained from key informants. This survey (Appendix 31) considered (1) recent rehabilitation and irrigation strategies and their impacts on nutrient status (2) collective fishing events. In addition, (3) qualitative test fishing was carried out in each tank to assess species diversity. A combination of gears was used in order to sample the broadest range of fish sizes and varieties. Fine mesh sweep nets were used in littoral areas and a 1.3cm (stretched mesh) cast net in deeper weed free areas. Results are presented in Chapter 5.

3.4.3 Baseline livelihood survey

This purpose of this survey was to collect baseline livelihood data on the households which would subsequently participate in the phase 2 longitudinal household monitoring survey (section 3.6). Survey panels consisting of three 'better-off', three 'medium' and four 'poorer' households were selected in each trial village. Subsequent re-classification and inclusion of an additional 'poor' respondent in GUR increased the total sample size to 41 households (Table 3.3). Selection took place according to a stratified random sampling design based on the outcome of wealth ranking (section 3.3.1). While the design included a higher proportion of 'poor' households, the target sample size was set at ten households per village for logistical reasons. This inevitably meant the sample was more representative of the smaller villages, i.e. almost 50% of the population was sampled in GBW, while the number fell to less than 10% in GUR, the largest village.

The survey which is shown in Appendix 24 solicited information in the following areas: (1) household demography (2) occupational characteristics (3) institutional membership and participation (4) exogenous kinship characteristics, i.e. out-with the immediate community (5) household assets, e.g. buildings, land and livestock (6) fishing participation (7) fish and fish substitute consumption characteristics (8) coping strategies.

Table 3.3 Sample design for baseline and longitudinal livelihood surveys after triangulation and reclassification of wealth ranks

Village / Wealth Rank	Poor	Medium	Better-off	Total
Maduragama	4	3	3	10
Lokahettiyagama	3[1]	4	3	10
Gurulupitigama	4[2]	4	3	11
Galenbindunewewa	4	3	3	10
Total	15	13	12	41

[1] 'Poor' household reclassified as 'medium wealth'.
[2] 'Poor' household reclassified as 'medium wealth' and new 'poor' household recruited to survey.

3.5 Monitoring action-research impacts

The action-research impact monitoring techniques listed in section 3.1.2 are described in the following sections.

3.5.1 Monitoring staggered harvesting

Direct observation was undertaken by project staff in the vicinity of any unplanned or planned fishing activity. Because of the impromptu nature of most events, key informants living in the proximity of the tanks were also recruited to assist with this along with other regular data collection tasks. Where opportunity and time permitted, fish were individually weighed and caudal lengths measured. A more rapid method involved bulk weighing and enumeration by fish species. A cruder technique requiring no weighing equipment, involved the use of photographic templates to sort fish into different weight classes in 25 to 50g intervals based on their overall 'size'.

In every instance, data were also collected regarding the type and source of fishing gears, loan terms, proposed fate of any catch and start and end times of fishing events. As in earlier surveys, personal and family details of participants were used to cross-reference wealth ranking results. The domiciles of external participants along with details of any intra-community relational aspects were also recorded. All participants were also asked to act as key informants; reporting on any fishing activity (including yield estimates), that they had participated in over the previous week or had observed others undertaking in the same tank.

3.5.2 Monitoring collective fishing

Non-participant villagers from neighbouring villages were recruited to assist research staff in data collection during collective fishing events. The following information was systematically collected through a combination of direct observation and post harvest measurements:

(1) *Yield*. The catches of individual teams were separated into three categories; *Oreochromis* sp., *Channa striata* and other small indigenous species (SIS) and bulk weighed using spring balances. Where time permitted, before bulk weighing tilapia yields were divided into three crude size categories; large > 150g, medium 100-150g, and small <100g.

(2) *Effort*. For each fishing group details were collected regarding start and end times, number and type of gears employed, mesh size and fishing techniques (i.e. driving or encircling).

(3) *Distribution*: In order to investigate correlations between wealth status, participation and yield distribution, the names and ages of local participants and those of their household heads were collected and cross-referenced against wealth ranking results. Individual participants were asked what they intended to do with their share of the catch. Details of any formal re-distribution to non-participants through the agency of village institutions were also recorded.

(4) *Conflicts*: Details of any conflicts arising as a result of collective fishing events and local capacity to resolve or mitigate the same were recorded.

Where high participant numbers in larger tanks precluded comprehensive data collection, priority was given to yield measurements. Any deficits in the other categories were then completed as far as possible using post harvest participant and key informant interviews. Other situational information was collected simultaneously using the checklist in Appendix 31. This process was repeated on successive days as long as a significant amount of collective activity (formal or informal) was observed to be taking place in each tank.

3.5.3 Test fishing

Test fishing using a ½ ” (stretched mesh) cast-net was carried out at 3 – 4 week intervals over 8 months between January and September 2001. While a set of gill-nets of various mesh-sizes would have allowed greater standardisation of fishing power, the technique was not practical for a longitudinal survey of this nature, i.e. active gill-net fishing would be unacceptable because of the loss of fish and risk of water quality deterioration.

An experienced local fisherman was recruited to carry out the fishing over the entire period. Fishing was limited to 10 casts on each occasion and restricted to deeper and relatively weed-free areas immediately below the tank bunds. Fish were weighed using a Salter spring balance (+/- 2g) and their caudal length measured. All fish were subsequently returned to the tanks. Other observations, namely breeding condition, colour and external symptoms of disease or parasite infestation were also recorded.

Beyond the above standardisation, cast-net fishing power proved highly susceptible to changing environmental conditions, e.g. water depth and area, macrophyte occlusion and turbidity (Murray 2004b). Larger fish (>100g) also proved highly resistant to capture and although visible, no snakehead were caught throughout the entire period. Consequently, little inference can be drawn from these results regarding the status of standing stocks. Instead they give some indication of species diversity and abundance, especially for smaller SIS which were relatively neglected in the other surveys. Length and weight data were used to calculate condition factors by species according to Equation 3.1. This measure gave an insight into the nutritional and reproductive status of populations in the different tanks.

Equation 3.1 Condition factor (CF) = Weight (g) / Length (cm) ^{3} x 100

Results from each of these methods were compiled in a single integrated relational data-base to facilitate data aggregation, reduction and cross-referencing for different analytical purposes (section 3.11).

3.5.4 Calculating catch per unit effort

Catch per unit effort (CPUE) proved to be an important determinant of villagers' inclination to participate in fishing activity (Chapter 5). While overall yield comparisons are relatively straight forward, for effort assessments careful consideration must be given to the suitability of measures for different environmental situations. To compare effort between larger perennial water bodies with persistent standing stocks, it is usual practice to standardise the fishing power of different gears, i.e. the relative effect that any gear has on fishing mortality over a given period of time (Sparre and Venema 1992). The most appropriate measures of effort would be linearly related to catch, i.e. the length of time for which a particular type of gear is set or employed in a specific manner (i.e. passively or actively) and the number or size of gears set.

In seasonal tanks, such comparisons are complicated by marked short term fluctuation in environmental conditions which influence fishing efficiency. Key parameters include: water depth, area, clarity and aquatic macrophyte occlusion. Collective fishing events involving multiple tank entry are likely to further accelerate such change. There is therefore likely to be significant interaction between these environmental factors, participation levels, the type of gear utilised and the way they are fished.

For example in larger / deeper residual storage areas (such as GUR, IMK and GBW, i.e. 1.7 -1.2m max depth) fish were typically driven into set gill nets by people wading and splashing. The efficiency of such effort increases with the number of people simultaneously involved. Areas of GUR^t were sufficiently deep for fish (especially snakehead) to escape below gill-nets which were mostly no more than 1.5m in depth. Rising turbidity increases gill-net efficiency still further as gears become less visible to escaping fish. In smaller residuals (i.e. SER), rather than driving fish into set gears they are more likely to be captured by drag-netting, i.e. sweeping gill-nets in an encircling or up-lifting mode. The high fishing power and mortality associated with the first day of collective fishing also results in dramatic declines in CPUE on successive days. This is further compounded by falling participant numbers.

Precise effort comparisons based on gear standardisation were therefore impracticable. Nevertheless, comparison of mean CPUE levels (Equation 3.2) with total yields calculated for different fish varieties and gear types over the entire CF period in each tank revealed some clear trends. These are discussed in Chapter 5.

$$\textbf{Equation 3.2}\ \text{Mean CPUE} = (\Sigma\, g_{d1 \ldots dn} (y_{v1 \ldots vn} / p / t)) / \Sigma\, g_{d1 \ldots dn}$$

Where:

g = Gear category (i.e. classified by type and mesh size)

$d_{1 \ldots d\,n}$ = Days on which collective fishing took place

y = Fish yield per gear (kg)

$v_{1 \ldots v\,n}$ = Fish variety (i.e. *Oreochromis* spp., *C. striata* or other SIS)

p = Number of participants deploying gear

t = Duration of fishing (hrs/gear/day)

3.6 Longitudinal household monitoring survey

The main purposes of this survey were (1) to improve understanding of how aquatic production from seasonal tanks benefit different wealth groups and (2) to asses the impacts of phase 2 interventions on the same groups. The survey involved repeat visits to households selected according to the same random stratified design used in the baseline livelihood survey (section 3.4.3). Longitudinal surveys, based on repeat visits to the same households or individuals (rather than different ones each time), are also know as ‘panel’ surveys and this term will be used to refer to this exercise in future. The survey both complemented and served as means of triangulating the direct observational and key informant techniques described in section 3.5. Interviews with the 41 participating households took place at 2-3 week intervals over a 14 month period from October 2000 to November 2001, i.e. most households were interviewed twice per month resulting in a total of 951 separate interviews. This periodicity, necessitated by the emphasis on staggered harvesting in the phase 2 trials, also meant that it became the most resource intensive monitoring tool in terms of manpower and data management.

The survey presented in Appendix 24 was divided into 9 sections:

1. Current household demography
2. Household food consumption and expenditure
3. Other major income expenditure
4. Household labour and subsistence income
5. Other savings and benefits

6. Livestock holdings / management
7. Water resource access / management
8. Collective and institutional participation
9. Semi-structured responses

A 'pilot' round of interviews (carried out during October 2000), was used to refine the survey, assess recall accuracy and to gain rapport with respondents. These results were excluded from the final analysis. Based on this assessment, section 2 was restricted to recall of the previous weeks' food consumption, while recall for all other sections was based on the entire interval between visits. Interviews took place with the household head, spouse or very occasionally elder siblings depending on availability.

3.7 Feed-back meetings

In phase 1 trials, community meetings were convened only at the onset and termination of trials. At least two additional feed-back meetings were held during the course of phase 2 trials in LHG, MAD and GBW villages. Where possible, meetings were incorporated into pre-existing forums already time-tabled for other community activities. Because of its more active and inclusive nature, the DDS replaced the FO as the primary forum for these meetings in phase 2 trials. During periods of intense agricultural activity, meetings (and household interviews) were held during the evening or on *Poya* days (a monthly Buddhist holiday), and took up to 30 minutes to facilitate depending on attendance and participation. An attendance audit, similar to that described in section 3.2.1.2, was also carried out at each meeting.

The following information was presented at each meeting using posters prepared by local research staff and village fishing society representatives (Plate 3.3):

(1) Review of stocking details (densities, sources, participation etc) and existing constitutional agreements.

(2) Wealth disaggregated mean monthly *per capita* fish consumption from intervention tanks and commercial or other sources. All volumes were also presented as cash equivalents using prevailing retail prices to demonstrate

income substitution benefits. Fish consumption levels were also compared to with those of other substitutes.

(3) Water management summaries and irrigation release profiles (Appendix 16 - Appendix 23, Murray 2004b).
(4) Test-fishing results and CPUE levels.
(5) Other issues, e.g. intervention related water-use conflicts.

Finally, there followed open and group sessions to discuss any modifications to integrated management options arising from these findings. Decisions taken in these or subsequent informal sessions related mostly to internal fishing restrictions (i.e. in terms of gears, timing and tank internal location) and means of restricting unsanctioned local and external participation.

Plate 3.3 Presentation of phase 2 longitudinal survey outcomes in LHG village

3.8 Participatory impact monitoring (PIM) survey

This survey was designed to investigate participant perceptions of change; positive or negative, that might have resulted from the trials. The survey was implemented in three phase 2 intervention villages; LHG; MAD and GBW. Results were compared with the more empirical outcomes of the other survey techniques described above and this in turn made an assessment of the efficacy of our adaptive learning strategy possible, i.e. what differences were there between actual and perceived outcomes. The survey which was the final monitoring exercise was initiated immediately after completion of the phase 2 trials between September and October 2001. The final design produced after recurrent field testing is shown in Appendix 25. The three main components of the survey are described below after a discussion of the sampling design.

3.8.1 Sampling design

Putative background variables determined from key informant interviews and long term familiarity with participant communities, were used to generate research hypotheses (Chapter 5: section 5.4). Table 3.4 shows the number of respondents in the survey cross-tabulated against four background variables; village, wealth, gender and age, envisaged *a priori* as being most likely to interact in the influence of preferences.

The design was most purposive in sampling representative numbers according to village, wealth rank and gender criteria, and less so for the remaining background variables due to the limited sample size. Representatives of 43-56% of households in each of the three villages were questioned resulting in a total of 57 cases; 14, 21 and 22 cases in GBW, LHG and MAD respectively. All households in the longitudinal livelihood survey were represented (n = 30) by at least one participant and additional respondents were identified from the wealth ranking exercise (section 3.3.1). Some 44% of poor households were interviewed compared to 28% each of medium and better-off households. Difficulties interviewing females without male interference resulted in an imbalance towards males (58%) over females (42%). Women were most significantly under-represented amongst the poorest LHG wealth group.

The two remaining background variables were incorporated retrospectively after completion of the survey. It was envisaged that both age and the distance of the household from the stocked tank may have had a significant impact on individual and household participation respectively. The distribution of these factors therefore arose as a consequence of the primary stratification described above. Both were recoded into pseudo-dichotomous variables to reduce factorial complexity. Two age-groups corresponded with the attitudinal differences described in Murray 2004a; greater or less than 40-years of age, i.e. where for cultural reasons the latter group are less likely to participate in fishing and to a lesser extent, fish consumption. While at 32% of total sample size, those above 40 years were well represented, only two better-off older males were interviewed in GBW. Some 56% of respondents came from households located less than 0.5km from the nearest intervention tank.

Other potential variables, such as FO membership or household size, were considered to be indirectly incorporated into the wealth stratification, while all villages were controlled for low-caste status and upper-watershed position.

Table 3.4 PIM sampling design; No. respondents based on three background variables: village, wealth, gender and age

Wealth	**Poor**				**Medium**				**Better-off**				**Total**	**%HH**
Gender	**Male**		**Female**		**Male**		**Female**		**Male**		**Female**			
Age (yrs)	**<40**	**>40**	**<40**	**>40**	**<40**	**>40**	**<40**	**>40**	**<40**	**>40**	**<40**	**>40**		
LHG	5	3	1	1	1	2	3	1	1	2	1	0	**21**	**45**
MAD	4	1	3	1	3	0	2	1	2	1	2	2	**22**	**43**
GBW	3	0	3	0	2	0	0	1	1	2	2	0	**14**	**56**
Sum Age	**12**	**4**	**7**	**2**	**7**	**2**	**5**	**3**	**4**	**5**	**5**	**2**		
Sum Gen	**16**		**9**		**8**		**8**		**9**		**7**		**57**	**46**
Total	**25**				**16**				**16**					

3.8.2 Recall of fishing participation and benefits:

Respondents were first asked to recall any benefits accruing, either to or from their household, through direct or indirect participation in any local seasonal tank fishery over the intervention period. This permitted an evaluation of the relative contribution of intervention outputs compared to the wider natural aquatic resource base. Separate responses were elicited for each of the discrete fishing periods identified in Chapter 5: (1) staggered - pre-spill (2) during spill (3) staggered - post spill (4) collective (5) post collective. Finally, respondents were asked to compare each of these results with the corresponding seasonal periods over the previous five years.

3.8.3 Ranking indicators of change

Fifteen indicators of change associated with the interventions were solicited from participants during piloting of the survey. For triangulation purposes (see below) these ‘participant-indicators’ were also grouped by researchers into six categorical or ‘category-indicators’ (Table 3.5). These groups doubled-up to 30 and 12 indicators respectively, to account for positive and negative impact directions (described below).

The indicators reflected changes taking place at two broad social scales: (1) the community and (2) the household level. Individual / intra-household differences were to some degree incorporated through the inclusion of male and female respondents in the sampling design.

Community level criteria were grouped under the ‘social cohesion’ category-indicator heading, while all other group and associated participant-indicators fell under the household heading. Farmers were asked to be very clear about these distinctions during the subsequent ranking exercises. Logical consistency was assessed using their previous recall data; for example, farmers recounting an anecdotal increase in food security with no observed improvement in their own household circumstances were advised to consider instead the community / social benefit indicators; ‘yield distribution’ and / or ‘internal participation’.

While the impact direction of most indicators (i.e. water quality, food security) was evident, others such as increased internal or external participation were less so. Consequently, farmers were also asked to clarify whether the intervention induced change created positive or negative impacts for their households or community. Benign changes, i.e. neither positive nor negative were recorded but not included in the ranking process.

Using the two sets of indicators derived above; a) ‘participant’ and b) ‘category’ (see Table 3.5), each respondent was asked to undertake each of the three following ranking exercises.

(1) *Optimal outcome ranking:* In order to assess how trial outcomes corresponded with participant preferences, respondents were asked to rank the six positive category-indicators in response to the conditional question ‘what positive changes *would* you like to have seen as a consequence of the interventions?’ As was the practice in earlier preference ranking exercises (section 3.3), respondents were obliged to rank all criteria and split ranks were assigned to criteria given equal significance.

Friedman’s test was used to assess the degree of concurrence between different respondents, followed by pair-wise comparisons for significant outcomes using Wilcoxon’s test. Both tests are suitable for related sample, non-normally distributed data (section 3.8.5).

(2) ‘*Participant-indicator’ and* (3) ‘*Category-indicator’ observed outcome ranking*: These two exercises differed from all the earlier ranking exercises in that they were concerned with participant perceptions of actual *de facto* outcomes rather than their conditional preferences. In this context it would unreasonable to compel farmers to rank all the indicators even in the many instances where no change was perceived. Consequently, a ‘multiple-response’ design was adopted. These arise when subjects are allowed to respond to more than one category of a multi-response variable (Decady and Thomas 2000).

In this instance, participants were first asked to state whether each indicator registered positive, negative or no-change; they were subsequently asked to rank only those indicators for which they perceived positive or negative change. This design brought the following benefits (1) It minimised the time expended on the exercise thereby also helping to maintain respondent concentration (2) A comparison of indicator citation frequencies (i.e. regardless of rank) can be incorporated in the impact assessment (3) It also meant that the broadest range of indicators could be retained, whereas preference ranking designs dealing with more than six indicators become increasingly problematic (Murray *et al.* 2004). Typically, this is dealt with by aggregating indicators into a smaller number of groups, often on an arbitrary basis (4) Because of the constraints described above, negative and positive impacts are usually assessed in separate ranking exercises; this makes it difficult to assess whether adverse outcomes outweigh benefits. The inclusion of directional change in a multiple-response design overcame this problem by compelling respondents to compare all positive and negative effects against each other during the subsequent ranking. Set against these benefits, multiple-response designs are more restricted in terms of the non-parametric techniques available to analyse them (section 3.8.5).

In addition to ranking the results, farmers were also asked to categorise any perceived change as marginal, intermediate or significant. This along with the two overlapping ranking systems and the participation recall section, facilitated detection of logical inconsistencies during the interview; in such cases, participants were asked to reconsider their responses.

Rather than unwieldy duplication of each indicator on the field recording form, a matrix was designed with a column to record the direction of change after which ranking took place (Appendix 25). Results were subsequently recoded to one of 12 and 30 possible conditions allowing for directional change in exercises (2) and (3) respectively (Table 3.5).

Table 3.5 Indicators of change identified by participants

	Indicator code			Indicator code	
Participant-indicators	**Positive impact**	**Negative impact**	**Category-indicators**	**Positive impact**	**Negative impact**
Institutional strength	1	16	Social cohesion	1	7
Multiple-use conflicts	2	17			
Internal participation	3	18			
External participation	4	19			
Water distribution	5	20			
Fish yield distribution	6	21			
Water quantity	7	22	Water management	2	8
Water quality	8	23			
Species variety	9	24	Food security	3	9
Species quantity	10	25			
Sale of fish	11	26	Income generation / substitution	4	10
Income substitution	12	27			
Time substitution	13	28			
Recreational activity	14	29	Recreation	5	11
Knowledge / awareness	15	30	Knowledge and awareness	6	12

3.8.4 Future impacts

This section consisted of three components: (1) participants were asked whether in the light of their experience they would like to repeat the exercise giving reasons for their answer. Four possible responses were elicited: yes, no, conditional (specifying the reason) or indifferent. (2) Secondly they were asked how in their view the previous year's results could be improved upon. (3) Finally assuming that sustainable adoption would depend on the participation or consensus of the wider community, farmers were asked how greater collective action could be achieved; again giving reasons.

3.8.5 Statistical analysis of PIM results

In this section I will describe the statistical analysis of the PIM results and simultaneously discuss some of the broader problems associated with assessment of this type of social data, i.e. whether significant perceptual differences exist between different interest groups. Three components were amenable to such analysis, one from each section of the PIM survey; the optimal outcome and impact ranking exercises from the first two sections and the nominal responses to the 'repeat intervention?' question in the third.

Participatory ranking (or scoring) techniques such as those described above generate subjective perceptional data measurable on an ordinal (non-continuous) or nominal (categorical) scale. Such data is amenable to non-parametric tests under which rejection of the null hypothesis of 'no difference' between respondents becomes more difficult than under corresponding parametric tests i.e. they have lower power (Wardlow 1985).

For ordinal level data from related samples, i.e. all criteria are scored by the same respondent, Friedman's and Wilcoxon's tests are the non-parametric equivalents of a one factor ANOVA and paired-samples t-test respectively; Friedman's test is used to ascertain whether significant differences exist in the opinions of different stakeholder groups. *Post-hoc* pair-wise Wilcoxon's median ranks tests are then applied to identify the precise loci of any such differences (the same method was employed in the analyses of water-use preference ranking results described in Chapter 2).

Development of non-parametric equivalents of ‘within-subjects’ multi-factorial ANOVA have lagged behind their parametric counterparts. However, recent years have seen great advances in analysis of multi-way contingency tables using a group of techniques collectively known as log-linear analysis (Kinnear and Gray 2000). Using these techniques higher order interactions involving more than two background variables can be tested. Such associations, which are beyond the scope of the Friedman / Wilcoxon method described above are often of greatest interest.

The method had three major limitations which restricted it’s application in this study (1) larger factorial designs require considerably larger sample sizes than the equivalent parametric tests; while the sample size was relatively large as a proportion of the total number of households represented in the three villages (i.e. 46%), the relatively low number of 57 respondents was modest in terms of the frequency counts required for the test. (2) it is unsuited to multiple-category responses from individual respondents, (3) although tests capable of dealing with multiple-response, related samples data are being developed (Decady and Thomas 2000), the log-linear methods currently available are applicable only to independent data (4) there is no contingency for split ranks, forcing respondents to make potentially unrealistic choices.

Because of these limitations only the dichotomous (yes / no) nominal response generated by question (1) of the PIM ‘future impact’ section; ‘would you like to repeat the intervention in future?’ was amenable to analysis using the method. To achieve the requisite cell frequencies, it was necessary to collapse factors into fewer criteria and run the analysis several times on different permutations of no more than three factors (including the response variable) per occasion. The response variable was itself collapsed from four possible responses; yes, no, conditional, or indifferent, to a pseudo-dichotomous yes or no. The five other background / grouping variables used in the analyses were; village (3) wealth, (2) age, gender (2) and km of respondent domicile from tank (2). The number of ‘collapsed criteria in each category are indicated in brackets. The factorial designs which are described in chapter 6 along with the data collapsing rationale, resulted in contingency tables containing no more than 12 cells per test, i.e. no greater than 3x2x2 factor criteria.

A hierarchical log-linear model is one where if a given interaction term is present then all lower order relatives are included in the model. A backward hierarchical elimination method was employed. This commences with a saturated model in which all component effect terms including all possible interactions are present. Consequently, there is 100% concordance between observed and expected cell frequencies. In an iterative step-wise process, all terms are sequentially tested and retained or removed in order to see whether observed cell frequencies can be adequately approximated by a model that contains fewer than the full set of 'treatment' effects. Testing proceeds down the hierarchy of complexity. That is, it commences with the elimination of highest order interactions and finally main effects.

The impact of removal on cell frequency is assessed at each iterative step until a contingency table with the simplest number of terms is derived which can account with reasonable probability for the observed cell frequencies. A goodness of fit test is used to test the effect of each subtraction, with a cut off for rejection set at or below the 0.5% probability level. Due to the small cell frequencies, a more conservative goodness of fit method known as the 'likelihood ratio' (LR χ^2) was used instead of the Pearson's χ^2 method. The procedure continues until the final model is achieved where no further elimination produces a decrement with a probability of less than 0.05. Finally standardised residuals for the 'best model' are calculated and goodness of fit re-assessed against the observed value, again using the LR χ^2 test.

The first and most important stage of analysis for the two remaining PIM datasets based on ranks, consisted of simple data-cross tabulations of permutations of up to3-4 variables simultaneously (using the pivot-table function within the Microsoft ACCESS® and EXEL® Office programs). Subsequently, both data-sets were also analysed using the combination of Friedman's and Wilcoxon's tests described above. In the second 'observed outcome' multiple response exercise, split ranks of lowest order were assigned to all 'blank' criteria on which participants perceived there had been no positive or negative impact, i.e. 'no change'. In the conditional 'optimal outcome' exercise the problem of blank cells did not arise as logically all criteria were ranked by all respondents.

A few final comments relate to the usefulness of the conclusions which can be drawn from perceptual data of the type collected in this survey and other social components of the research. Firstly, the loss of ‘magnitude’ implied in ordinal or nominal level data means that one can only make inferences regarding the order of criteria importance, rather than exactly how important these outcomes were to different interest groups. One possible response would be to also ask whether any perceived impact resulted in a ‘marginal, intermediate or significant’ benefit or loss to individual respondents or their households, underpinned where possible by a quantitative definition. This would generate an additional categorical variable amenable to log-linear analysis. In this PIM survey, an attempt to evaluate the importance of any overall change was addressed in the final ‘future conditional’ question ‘would you like to repeat the intervention again in the future?’

A further and more general limitation associated with attempts to quantify individual interest perceptions through ranking arises when people are not fully adept at evaluating their own preferences or when wishes influence their beliefs. It is then misleading to conceptualise people as attempting to maximise stable, well defined utility functions from a purely economic perspective. Furthermore, in situations of extreme poverty, the poor often internalise the severe constraints they and earlier generations faced. This manifests itself as fatalism, low aspirations, low perceptions of needs and high rates of time discount (i.e. people give low value to their time – Sen 1999). These problems were manifest in the outcomes of action research described in Chapters 5 and 6, most notably with respect to the lowest income groups. In other words, wherever possible, such techniques should ideally be complemented with direct observation of what people actually do.

All statistical analysis (log-linear, Friedman’s and Wilcoxon’s tests) were undertaken using SPSS version 12 except where indicated.

3.9 Cultivation strategies survey

During Sep-Nov 2001, a ‘cultivation’ survey was administered to each of the 41 households that had previously participated in the longitudinal household survey (i.e. alongside the PIM survey – section 3.8). Respondents were asked about their cultivation strategies and actual outcomes during the *maha* 00/01 and *yala* 01 seasons. Information was elicited regarding the three main farming systems; irrigated, home-garden, and *chena* cultivation. Access rights were classified for each production site. Next, for each system, season and crop, information on quantity, cost and timing were elicited for the following inputs and outputs: seed requirements (and sources), organic and inorganic inputs, labour and capital requirements and harvest outcomes (including the fate of any harvest). Finally, farmers were asked about sources of agricultural information / extension and asked to describe how this plant and livestock production outcomes related to trends in production over the previous 10 years. The full survey is presented in Appendix 26.

3.10 Irrigation practices

Irrigation practices under the five phase 2 intervention tanks were assessed during the 2001 *maha* and *yala* cultivation seasons (Table 3.1). Monitoring was based on weekly key informant interviews triangulated with direct observation. Information was collected on the frequency, extent, duration and synchronisation of irrigation and the number of farmers participating. Details of individual land holdings along with lease and share cropping arrangements were also collected. The dates and extent of irrigation releases (ha irrigated / day) and the onset dates for collective fishing are plotted together with seasonal water storage profiles derived from the separate tank hydrology survey in Appendix 21 (Murray 2004b). Results are discussed in Chapter 4.

3.11 Data management and analysis

The longitudinal nature of many of the surveys generated a substantial volume of data; for example, the food consumption component of the household survey (section 3.11) generated over 8,000 records alone. This necessitated an efficient data management solution to avoid the data wastage frequently associated with such surveys. Microsoft Access® was used to create a fully de-composed relational database facilitating data validation, data reduction, cross-tabulation, cross-referencing and basic statistical exploration of results. The design also enforced an *a priori* consideration of analytical methods and improved speed of data entry. Raw data, summarised as frequency distributions, could also be rapidly exported to other packages such as Microsoft Excel® and SPSS® for more detailed analysis.

Relational design is also suited to horizontal (i.e. once-off rather than recurrent) surveys which are either large and / or asymmetric, e.g. demographic surveys where there are a variable number of occupants in each household. Consequently, as many surveys as possible were incorporated in the design. This facilitated inter and intra-survey cross-referencing and a far more wide ranging exploratory analysis than would have been possible with a ‘flat’, two-dimensional spread-sheet application. The same coding systems could also be applied to many different surveys resulting in dramatic efficiency gains. Ultimately, all primary data-sets including, marketing, watershed typologies and all action-research surveys described above were incorporated. Only the water quality and tank hydrology datasets with their relatively flat / symmetric design more suited to simple spreadsheet manipulation were excluded. Semi-structured comments were appended into the most relevant structured data tables. This made them readily accessible for interpretation of quantitative analytical outputs.

The inflexibility of externally contracted database systems is one of their greatest drawbacks, particularly for surveys incorporating some degree of semi-structured design. ‘In-house’ development allowed ready modifications to be made to the relational design during the piloting phase and when necessary thereafter.

The longitudinal household survey was by far the largest of all the surveys. As with many ‘panel’ type surveys’ numerous asymmetry problems were encountered. These were a consequence of (1) uneven numbers in the different wealth groups (2) difficulties maintaining uniform intervals between visits (3) seasonal fluctuations in household occupancy. These factors made aggregate calculations such as *per capita* consumption characteristics much more complex. Here again the use of a relational database provided an efficient means of manipulating such a large dataset. Mean *per capita* consumption levels were calculated based on the number of individuals within different sub-groups as follows:

1. Using household occupancy results, total cumulative populations were cross-tabulated against population sub-variables (village, wealth rank and relational categories) and time-base variables (months or years) of specific interest. The numbers of individuals in each group were calculated inclusive of both consumers and non-consumers.

2. Results of recall on the previous week's total household consumption (kg) for specified food items were divided by their respective denominators calculated in step 1.
3. Results of step 2 were divided by 7 (1 week being the consumption recall period) and multiplied by 30 to yield monthly values; or, finally multiplied by 12 to yield annual values. All annual *per capita* consumption levels were calculated between; Dec 00 to Nov 01 discarding results from Nov 00; the first and least reliable month of the survey.
4. The preceding calculations were made at the lowest aggregate levels and finally summed over the different background variables to reduce rounding errors.

Subsequent exploratory analysis was based on cross-tabulation of these results using the pivot table functions of Microsoft Access® and Excel®, or exported to SPSS® for more detailed statistical analysis. A CD containing a copy of the relational database is presented in Appendix 37.

Chapter 4 Village characteristics

4.1 Introduction

In this chapter I discuss the main forms of settlement in the Dry-Zone of Sri Lanka focusing on the traditional *purana* villages (meaning ‘inceptive’ or ‘initiatory’ according to Carter (1982), or ‘belonging to former times’ – Encarta 2005) which still predominate in extensive rainfed areas of the Sinhalese hinterland. I begin by investigating secondary sources in order to describe the historic trends which have given rise to their present social structure. I also give details of the principle farming systems which traditionally underpinned livelihoods in the Dry-Zone. In the second section, I compare and contrast these findings with the results of social surveys (Chapter 3) in villages of the Giribawa and Anamaduwa research areas. Emphasis is on the villages that subsequently participated in action research.

While large-scale irrigation and its accompanying socio-political forms have featured prominently in the historical and anthropological literature, less attention has been given to small-scale community-managed works. A notable exception in Sri Lanka is Leach’s 1954 study of a community near Anuradhapura, to the North of the research area. He gives a detailed description of the customary rules based around caste and kinship and their role in creating social boundaries, which perpetuate inter-generational patterns of access to scarce resources, including land and water (Leach 1961). Other important contributors include; Farmer (1957), Sarkar and Tambiah (1957), Obeyesekere (1967),Tennekoon (1974),Samaraweera (1978), Abeyratne and Perera (1986) and Madduma Bandara and Godigamuwa (1991).

Section 1. Development history of the *purana* village

4.1.1 Evolution of the Dry-Zone *purana* village

Despite its relatively inhospitable climate, the Dry-Zone of Sri Lanka became the seat of a flourishing civilization dating back to at least 300 B.C. Water rather than land ultimately set the limits to cultivation and the size of the population that could be supported. A gently undulating topography facilitated the construction of storage tanks consisting of simple earthen dykes across seasonal streams which provided supplementary irrigation for paddy cultivation (Chapters 3).

From the earliest times, small village irrigation systems were also the focus of community life; socially, economically and politically. These social structures evolved alongside advances in irrigation engineering, which developed to such a level of perfection that historians often speak of a 'hydraulic civilisation'. The development of larger and more complex irrigation systems permitted the establishment of cities supported by a type of service tenure known as *Rajakariya* (meaning King's duty, or literally 'work for the King'). In this feudal system, services due to the King or Buddhist monastic estates were determined primarily according to caste (Leach 1961, section 4.1.9.1). Tank construction and maintenance for example were often entrusted to a specialised Tamil caste known as *Kullankatti*. However, the central government did not concern itself with village tank management. Consequently, when government was disrupted and major works fell into disrepair, village communities were able to survive at a subsistence level supported by rainfed cultivation in 'dry-land' areas and cultivation under their village tanks (Wickremeratne 1985, Woolf 1913, Chapter 2).

The decline and subsequent collapse of this civilisation towards the end of the 12th Century AD has been attributed to a combination of social and environmental factors. Some authors suggest a build up waterborne diseases such as malaria (Nicholls 1921) and / or soil salinity. Others maintain that the anopheline vector was already present and suggest that it had more to do with foreign invasions and internal dissension resulting in the decay of the irrigation infrastructure (Konradsen, Amerasinghe *et al.* 2000). Similar causes have been attributed to decline of the Khmer civilisation centred on Angkor Watt which also relied on highly engineered, large-scale irrigation

(Coe 2003). Whatever the true cause(s), all that remained in much of the Dry-Zone interior at the time of the arrival of British colonists in 1796, were scattered tank villages where farmers lived at subsistence level (Abeyratne 1956). Thereafter, the Dry-Zone remained a condemned, sparsely populated area until the 1940s when malaria was finally brought under control and tank renovation began in earnest.

4.1.2 The *purana* village

The Dry-Zone *purana* village of the past constituted a well defined social and physical unit. As noted above, each village was essentially self sufficient within the limits imposed by the need for an inter-linked system of irrigation (i.e. within cascading tank systems - Chapter 2), and exhibited a high degree of social organization. Village unity was achieved partly by social homogeneity in terms of caste, kinship and religion, the application and enforcement of rigid laws and social customs and the joint effort for survival in a water-scarce environment. Physical demarcation was essentially watershed based; '*verala*' the term for a village boundary (literally meaning 'something in-between' such as a shore) was synomous with the notion of catchment area. Each village was therefore a natural and easily definable physical unit with control of all the lands vital for its existence; the immediate catchment area above any tank, its forest and pasture, the rice fields below and the tank itself (Abeyratne 1956).

Clusters of homesteads (*gangoda or gammadi*) were located on elevated land along each side of the tank alongside the paddy fields. This had several benefits; drought-susceptible trees such as coconut and shrubs grown in home-gardens could benefit from elevated groundwater levels, shallow drinking wells could be sunk here and the tank catchment would be preserved. Most villages would have been home to no more than 50 families (Abeyratne and Perera 1986). The valley floor known as '*wel yaya*' was cultivated with rice, receiving supplementary irrigation from the tank. Cleared areas of forest in the un-irrigable uplands were used for rainfed, shifting ('*hena*' anglicised as *chena*) cultivation of crops such as: millet, corn, cassava, pulses, chili and other hardy vegetable varieties. This traditional land-use pattern is still at the core of today's Dry-Zone farming systems (section 4.2).

4.1.3 The colonial period

Progressive change came with colonial rule and the advent of a cash economy. However, until the 1930s, the predominant theme of the British policy of indirect rule was to institutionalise customary forms of social organisation at village level. Thus despite abolishing *Rajakariya,* they supported the continuation of irrigation management under traditional *Gamsabava* (village tribunals) combined with a newly instituted position of *vel vidane* (irrigation headman). This system worked satisfactorily, as although elected, the *vel vidanes* still tended to come from the old elite village families. They thereby courted a traditional respect and had less need to resort to formal sanction. Secondly, they were accountable to the irrigators from whom they received a small share of the harvest. Both parties therefore had a common interest in sustaining or increasing production, while an efficient revenue system was established for the colonial power.

4.1.4 The post-independence period; demographic and structural change

More rapid and far-reaching changes followed independence in 1949. Improved health services and virtual elimination of malaria with the advent of DDT spraying campaigns resulted in a widening gap between fertility and morbidity. This resulted in the island's population doubling between 1930 and 1963, with the rate of natural population increase peaking at 3% per annum in the 1950s. Urban job opportunities have essentially remained static relative to population growth accentuating the pressure on cultivable land. This in turn has resulted in land fragmentation and increasing landlessness. Dependency ratios also rose with the proportion of youth in the population placing additional pressure on the new welfare system.

These demographic trends have led to the extensive re-colonisation of the Dry-Zone accelerated by a policy of resettling population; often entire village communities from the over-crowded hill country. These movements were supported by an ambitious scheme of structural improvements including development of major irrigation systems; most notably the Mahaweli scheme which will ultimately irrigate some 365,000ha of land in the Dry-Zone by diverting water from the countries largest perennial river (Wanigaratne 1997). Less visibly, restoration of thousands of abandoned village tanks has taken place over the same period, though with a much lower level of government support.

Consequently, apart from a few modestly-sized towns, two forms of settlement have come to predominate in the Dry-Zone. Modern 'irrigation colonies' are service centres for large irrigation systems and thereby benefit from good physical infrastructure. They typically consist of between 1,000 - 2,000 households belonging to mixed kinship groups (Kodithuwakku 1997). These colonies are interspersed by the smaller traditional *purana* villages settled around seasonal tanks in more isolated rainfed areas usually home to between 10 – 500 households. As *purana* villages too have expanded, the tracts of forest separating them have become ever smaller.

The interspersion of these different settlements and their associated tanks also means that today, many *purana* villagers have come to rely on opportunities under major schemes for a significant part of their livelihood. Over the last three decades, longer term migration associated with remittance labour opportunities for women in an expanding garment sector or as housemaids in the Middle East, has presented a further challenge to the social cohesion and tradition of these communities.

4.1.5 Political and social change in the modern era

Village communities had remained inwardly orientated in their socio-economic and political activities until the 1930s. The accelerated expansion of state activity in rural areas in the post-colonial period caused these hitherto closed communities to evolve into wider socio-economic and political units. Two interrelated factors were of particular significance; the advent of a state welfare system and the politicisation of administrative links which has increased the role of patronage in public life (Perera 1985). Apart from the lowest tier of public servants such as the *Grama Niladhari* and *Samurdhi Niyamakes* (Chapter 1) who are in regular touch with rural people, many government service agencies have established village level organisations such as; farmer organisations, cooperative societies and rural development societies. These institutions in some ways replicate various arms of the state at village level.

As in many other developing states, the three decades following independence also saw the progressive movement towards a centrally planned economy. This resulted in the tank resource effectively being taken into public ownership, eroding the local sense of ownership which had traditionally fostered responsibility for tank maintenance as well as operation. Without effective community cooperation, state management of such a widely dispersed micro-resource was never likely to be feasible. With the recent emergence of a more participatory paradigm, in which the interests of government fiscal policy and development policy converged (Chapter 1), there were concerted attempts to reintroduce this responsibility. This has proved difficult to effect given the entrenched dependency culture that the earlier policy has fostered.

Declining economic performance during the centrally planned era (1950-1977) resulted in Sri Lanka becoming the first south-east Asian state to seriously begin liberalising its economy. Whereas neighbouring states continue to shield much of their agricultural sector (*Economist* 2001), in Sri Lanka, input subsidies and guaranteed markets for agricultural produce have been substantially removed. However, government policy on the international trade of agricultural produce has proved highly erratic (Tudor Silva *et al.* 1999). This has had the effect of further increasing uncertainty and risk for small-scale producers of cash crops, and has discouraged further uptake of their cultivation.

4.1.6 Development strategy and liberalisation

Much debate currently revolves around the effects of free-market forces on traditional village social structures and their institutions (Tudor Silva *et al*. 1999). In this respect Sri Lanka can provide valuable insights to neighbouring regional states that have been slower to liberalise their agricultural sectors. From a development perspective, a frequently posed question, is to what extent is it feasible to seek to improve lives of rural people through action directed purely at the village level given these increasing external forces? (Brow 1992, Howes 1998, Silva *et al*. 1999). For example, as will be shown below, many villagers in the current study, increasingly rely on external 'off-farm' activities, both agricultural and non-agricultural, for a significant part of their livelihood.

There are those who argue that relentless liberalisation will make it futile to re-invigorate subsistence based forms of production. However, even if this extreme view is accepted there is still an interim need to provide an adequate safety-net for the many struggling on the margins of the market. Howes (1998) suggests that some accommodation must be achieved between the free market and more self-sufficient traditional community social structures. However, exactly what constitutes such a compromise is itself problematical.

4.1.7 The Dry-Zone village as a social construct

Recent development thinking and practice in Sri Lanka has been shaped by a dominant, hegemonic nationalist ideology fostered by the Buddhist / Sinhalese State and some local NGOs (Silva 2002,Gombrich and Obeyesekere 1988). This ideology sees the essence of Sri Lanka, its cultural and moral past and future destiny, as being bound to its traditional village life. This has contributed to a naïve view of an idealised traditional village characterised by homogeneity, harmony, apolitical self-sufficiency, isolation and perfect adaptation to the environment (Brow 1992, Silva 2002). The simplistic stereotypical trinity of tank (*wewa*), paddy field (*ketha*) and temple (consisting of the monks residence (*pansala*) and stupa or *dagaba*) symbolised the social, economic and spiritual life of the community thereby providing the foundation for existence in a 'nation of villages' (Woost 1990, Brow 1998). These conditions in turn are viewed as precursors for 'prosperity, peace and well-being' (Silva 2002).

In reality, villages are best viewed as potential sites for a range of conflicting-micro political interests. Only a small number of villages ever approximated to the ideal described above, or more likely the conditions represent a composite of life in numerous subtly different social settings. Yet as the State has penetrated into rural life, this idealised view has been the basis for inclusion or exclusion, patronage or discrimination in terms of the distribution of scarce resources such as land or water (Silva 2002).

Clearly, the nationalist construct has also spilled over into development discourse, shaping its practice by both local and international organisations. *Sarvodaya* is an eminent local development organisation whose spiritual ethos is based on a so-called 'Protestant Buddhist' revival dating back to the British Colonial period (Gombrich and Obeyesekere 1988). The organisation, which has attracted considerable international attention and financial support, has been particularly successful at promulgating the sentimental vision of village life described above and while it has been successful at mobilising collective action through voluntary work groups (*kakiya*), ultimately it also serves to reinforce the position of middle-class urban elites above their village counterparts (Gombrich and Obeyesekere *ibid*).

For technically-orientated government line agencies, adherence to this simplistic view is also compatible with sectoral / technical approaches which 'reduce' complexity and are easier to scale up. Even where the social and physical indivisibility of the *purana* village is recognised, rarely has this corresponded with any meaningful integrated development strategy (Dayaratne 1991).

The 'one village one tank' element of the construct's reductionism is of particular significance to this study. As I will show, even the very smallest villages have access to two or more tanks, while the largest intervention village (Ihala Maradankadawala - IMK) had 19. These resources are demarcated in time and space for a range of competing users and uses. In the following section, I coin the term '*purana* complex' (PC) to highlight aspects of this physical and social complexity.

4.1.8 The *purana* complex

Traditional settlements in rainfed areas of the Dry-Zone are known as *purana* ('old') villages. In the current study, the oldest *purana* villages (>150 years old) tended to be established around the most reliable perennial or larger semi-seasonal (non-system) tanks, typically in an axial position. I shall refer to these as 'base-tanks'. Most villages would have one such tank which became the focus for primary settlement. Some characteristic of this tank, often the type of trees growing around it, usually then gave both the tank and the village their name. Subsequently, farmers extended irrigated cultivation to smaller more seasonal tanks adjacent to the base-tank(s). Larger tanks, higher or lower in the cascade were likely to have been colonised by other groups, thereby imposing limits on 'vertical' colonisation.

At first, the satellite tanks were likely to have been used to irrigate cultivated land on a rotational basis. However, rapid population growth since the 1930s has progressively resulted in permanent settlement. This has occurred through both informal encroachments and formal village expansion schemes. However, ownership of much of the irrigated land under the original tanks, and therefore the primary control of water, frequently continues to reside with more affluent older farmers around the base-tanks (Murray 2000c).

I will use the term '*purana* complex' (PC) to describe these discrete social assemblages which share well-defined spatial and temporal access to a range of natural resources centred around water storage. Such a PC may cover all or a large part of a catchment, depending on the catchment size and its hydrological endowment. Figure 4.1 shows a typical PC arrangement, while maps of each of the Giribawa PCs in which stocking interventions took place are shown in Appendix 28.

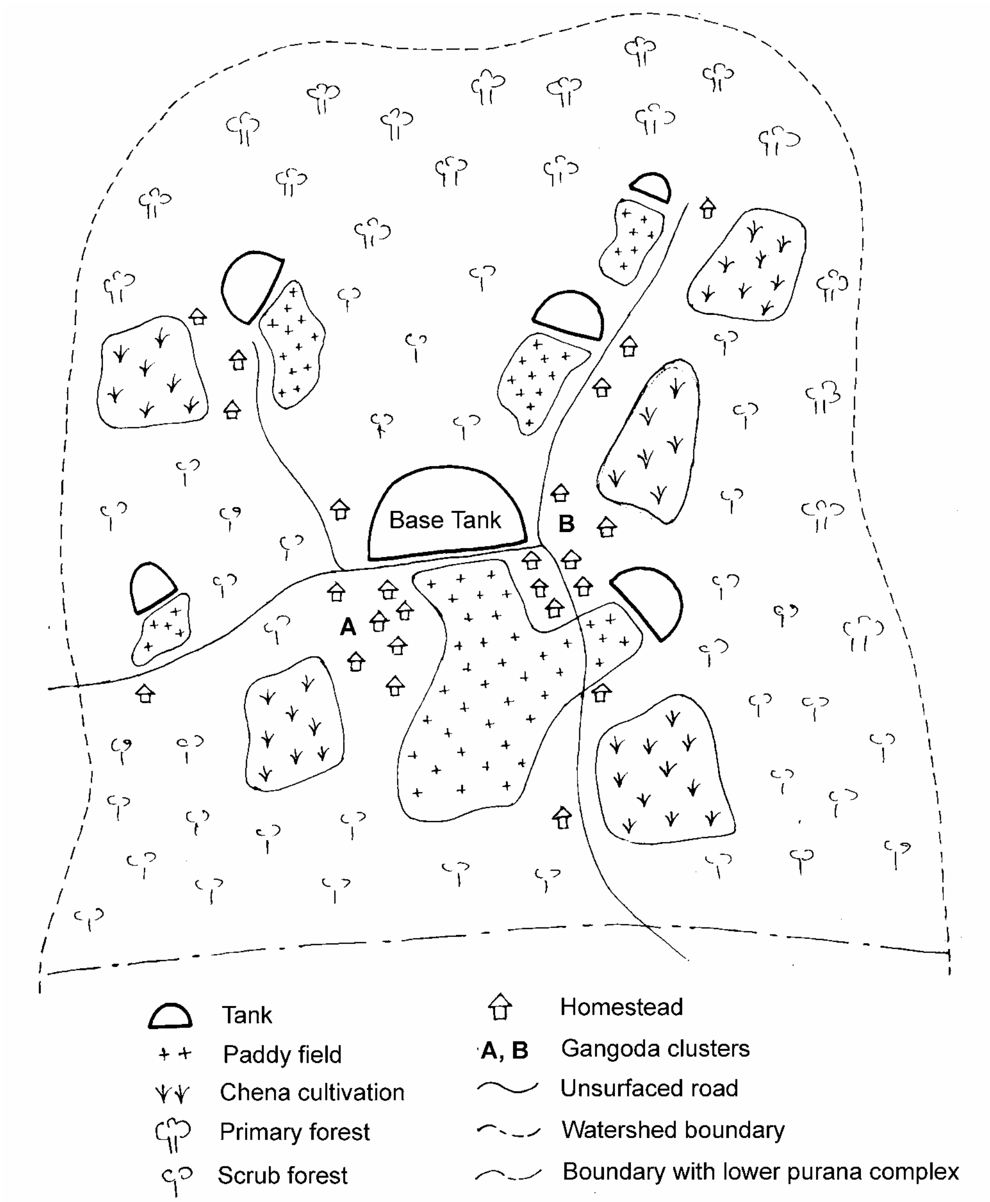


Figure 4.1 Schematic diagram of a typical upper-watershed '*purana* complex'

4.1.9 Social stratification: caste and kinship

4.1.9.1 The caste system

The caste system provided the traditional basis for a hierarchical, feudal social ordering, that ensured performance of all functions necessary to society. The system pervaded social, political, economic and religious spheres. Srinivas (1998) commenting on caste in India, observes that it effectively served to preserve inter-generational privilege based on status at birth yet, despite its intrinsic inequity, it simultaneously conferred a high degree of social stability. Caste served the same primary role as a social institution in Sri Lanka.

All caste systems are similar in as much as they function by excluding kinship links of all kinds, and thereby effect external relations between different caste groups (Leach 1969). Where they differ, and of key interest in this study in terms of access to water resources, is the degree to which caste groupings coincide with the boundaries of territorial groupings.

During the last century, the formal institutions of the Sinhalese caste system were progressively broken down. Yet inter-caste marriage is still rare in rural areas. More symbolically, entry into many sects of the Buddhist *Sangha* (priesthood) is still restricted to particular castes or sub-castes (Gombrich 1971), while since independence, there has been elitist polity based on caste and clan divisions. Consequently, the social organization of communities into caste groups remains fundamental to the power structures that still shape patterns of land and water rights in rural areas (Perera 1985). This is true of both Tamil - Hindu and Sinhalese - Buddhist societies.

Amongst both groups in Sri Lanka, the land owning cultivator castes are both most dominant and numerous. Whereas caste provided a basis for internal labour-division in many South-Indian Hindu villages, including specialized irrigation labourers and functionaries, in Sinhalese *purana* villages, single-caste communities were, and still largely remain the norm (Ryan 1953, Tambiah 2000).

The dominant *Goyigama* land-owning caste, which still constitutes more than 50% of the Sinhalese population, was itself stratified into at least three sub-groups (*wanchi* or *jati*). Foremost were the *radala*, aristocrats and administrators, who were granted ownership of large estates in return for their patronage by the King. Below the *radala* were two tiers of *Goyigama* peasants who cultivated small holdings and were distinguishable mainly by the extent of their lands. The majority of farmers fell into the upper of these two tiers (*Govivanse*) from whom petty officials were also occasionally drawn (Yalman 1969).

The remaining non-*Goyigama* lower order castes were essentially service providers to the aristocracy, temples or neighbouring communities, in return for which they were granted access to cultivable lands as tenants or share-croppers. In many instances the traditional service-designations of the latter groups referred only to ritual duties, e.g. drummers (*Berawaya*), palanquin bearers (*Paduvua*) etc. (Table 4.2). Occupationally therefore, in the past as today, they were also primarily cultivators (Leach 1961). Similarly, many amongst the lowest tier of the *Goyigama* who were landless farmers also relied on patronage of the *Govivanse* for access to cultivable lands.

Three major castes found mainly along the southwest coast, *Karava* (fishermen), *Durava* (toddy-taper), and *Salagama* (cinnamon peelers) elevated themselves from a low or marginal status by occupying business and academic positions during the colonial period. This has accorded them a rank equal to or slightly below the *Goyigama*. The Tamil fisher caste (*Kairaya*) elevated themselves in a similar manner reducing the gap between themselves and the elite Tamil cultivator caste (*Vellala*).

Leach (1969) argues that the grades with a single caste, such as those of the *Goyigama* described above are more akin to social classes in as much as there is constant competition between the different grades for similar kinds of merit. The separation between different named castes he argues is much more absolute 'almost as if they were different species.' Yalman (1969) suggests that the relative 'lowness' of different communities depends on a combination of three elements (1) traditional names specific to different castes (2) occupation and (3) communal distinction. He suggests only those groups which formed closed endogamous communities received enduring designations regardless of occupation, i.e. for this reason there is no specific carpenter caste. This communal distinction also indicates that by leaving the immediate community, individuals could more readily sever their caste (and kinship) linkages than is the case in the Hindu tradition where religious notions of pollution are more entrenched.

4.1.9.2 Kinship – the *variga* system

In addition to their single-caste status, inhabitants of traditional *purana* villages considered themselves to be members of a single *variga* (sub-caste) based on endogamous kinship. In this system the favoured marriage was between cross-cousins living in the same village. These groups avoided association with alien (*pita* – literally 'outside') *variga* particularly in marriage and funeral ceremonies. The *variga* was territorially based, taking the name of the village and its membership was decided by a formal *variga* court consisting of influential village elders.

The court was able to sanction rules through fines and the ultimate threat of expulsion. Same-caste exogamous marriages (i.e. inter-community) were permitted with approval of the court (Perera 1985). Virilocal (*diga*) marriages, where a man brought a woman from another village or local household to his own household, were more favoured than the opposing form of uxorilocal (*binna*) marriages. These usually involved poorer men seeking access to land through marriage, but this did not bring automatic inheritance rights which generally favoured wife and off-spring. Furthermore, other obligations of the son-in-law towards his in-laws would also increase (Yalman 1971). Consequently, the position of *binna* husband, which could carry inter-generational stigma, was far more precarious than that of a *diga* husband.

In principle therefore, *variga* endogamy restricted access to common village lands and tank resources to *variga* members, and, on the surface at least, a relatively egalitarian system prevailed when all belonged to the same *variga* and social cohesion was enforced by the obligations towards each other. However, in his study of 'Pul Eliya', Leach (1961) observes 'that most internal disputes were over rights to irrigation water' and in such a dispute 'the objective of the stronger party is to force his opponent out of the village. The traditional way of doing this was to get him convicted in the *variga* court' under some pre-text of transgressing *variga* rules. Using this and other examples, he demonstrates how, in practice, hypocrisy and discrimination were common place in the operation of the court to the point where rules of exclusion or inclusion were flexible if sufficient guile or influence could be exercised.

Such observations underscore the dynamic essence of kinship structures which are in practice are always in the process of change (Harris 2005). Nevertheless, it is still possible to argue that *variga* groups are endogamous in a broader functional sense. Overing Kapalan (1975) descibes multiple forms of endogamy, of which three broad definitions are of relevance here. The first between cousins or sibling sets in different generational tiers is the 'aspirational' form in the *variga* system described above. The second involves multiple repetition of serial affinal ties i.e. a couple may marry because they are already have siblings-in-law as a result of an earlier exogamous marriage in their family. Finally there is endogamy through geographical proximity. Together these forms characterise the majority of marital relations recorded by Leach in Pul Eliya. Therefore what at first may seem a relatively random and flexible social organisation actually has a remarkable degree of intrinsic stability and continuity.

Just as the economic roles traditionally associated with the caste system declined with the abolition of the Kandyan feudal system, so did the formal institutions of *variga*. Although in some instances astute Government Agents incorporated the *variga* court into the system of indirect British colonial rule i.e. as part of wider patronage system in which they reinforced the position of traditional village leaders. Leach (1961) records a court in 'Pul Eliya' functioning in this manner up to 1938.

At a more fundamental level, the 'homogeneous' one village one *variga* social organisation began to be challenged by inter-village migration as population levels rose in the latter part of the 20th Century (Perera *ibid*, Gombrich and Obeyesekere 1988). However, even with such enforced proximity, outsiders, particularly those of lower caste status would be considered as an inferior group (*varigen pita minissu* – those without pedigree) and interaction limited to agricultural work. Such change was most marked in the over-crowded hill country. In the Dry-Zone, new irrigation colonies provided opportunities for incomers. Existing *purana* communities had more room for expansion in rainfed areas and perhaps have been subjected to slower rates of change. Although there is clearly still great homogeneity in terms of caste, religion and ethnicity at least, *variga* inter-mixing is an on-going process, with implications for the future development of land and water access patterns.

4.2 Farming systems

A farming system is a unique arrangement of farming enterprises and associated practices that a household undertakes in response to its physical, biological, and socio-economic environment, in accordance with household goals, preferences and resources (Lightfoot *et al.* 1992). The main traditional systems in the Dry-Zone of Sri Lanka are (1) paddy cultivation (2) *chena* cultivation (3) homestead cultivation and (4) livestock production. *Purana* villagers traditionally derived most of their income and subsistence from the first two of these categories. The main categories of cultivable land, their tenure and the production relationships amongst the cultivators are discussed in the following sections.

4.2.1 Rice cultivation

Rice remains the staple food of Sri Lanka and a central component of Dry-Zone farming systems despite low rainfall levels (Plates 4.1 A and B). This is a result of the relative ease with which it can be grown, its excellent storage characteristics, liquidity (there is always a market) and a strong cultural attachment to its production (Tudor Silva *et al.* 1999).

Rice was grown in the valley floor using supplementary irrigation from village tanks. The area immediately below the tank bund called the *purana wela* (old field), had best access to irrigation water and double cropping of rice would be possible in a normal rainfall year. Private holdings in the old field were called *pangu.* Lands located further away from the tank, on the periphery of the *purana wela*, were known as *accara wela* (field blocks) where double cropping was less feasible. Rainfed rice was also grown on the un-irrigable lower slopes called *wi-hena* (Madduma Bandara and Godigamuwa 1991)

Traditional rice varieties were long strawed and low yielding, i.e. 1 - 1.5 mt ha^{-1}. Modern high yielding varieties under supplementary irrigation yield on average 3.1 - 3.6 mt ha^{-1} (FAO 1996). At the same time, average land holdings have fallen to 0.2 - 0.4ha (GoSL 2000).

Land preparation for irrigated production during the main (*maha*) cultivation season typically begins around November or when tanks are at least two thirds full. The second (*yala*) crop is usually planted in April, with the onset of the lesser SW monsoon. Farmer responses to reduced water availability included reducing the extent of cultivable land under a flexible freehold system known as *bethma*, while 4 - 4.5 months duration rice varieties would be grown during the *maha* season and 3 - 3.5 months varieties in *yala*. However, during below average rainfall years, cultivation would frequently be abandoned entirely. In the past this elevated the importance of the dry-land components of the farming system, *chena* and homestead cultivation, to basic household food security.

A …….B

Plates 4.1 A and B: Paddy field preparation (A) and harvesting (B) under Hangogamawewa tank, Maduragama village, *yala* 2001

Cultivation decisions were determined by the anticipated returns to labour as well as risk assessment based on water availability. Consequently, while *chena* practices have changed little and yields remained static, the advent of higher yielding green revolution rice varieties over recent decades has made paddy cultivation relatively more attractive. The relationship between yields, land holding and subsistence consumption or sale of rice is discussed in section 4.3.11.

4.2.2 *Chena* cultivation

Traditional *chena* (Anglicisation of *hena*) was a form of shifting slash and burn cultivation usually practiced on upper slopes above and adjacent to the village tank(s), where it was referred to as *goda hena* (Plate 4.2). The forest under canopy was cut and burnt during the dry months of July and August, and the mineral rich ash would fertilise the crop. No further inputs were required and many of the crop seeds were simply mixed together and dry-cast at the onset of the NW monsoon rains (October to November); the main crops would then be harvested during January and February. A variety of cereals, pulses and dry-land vegetables were planted. *Kurakkan* (*Eleusine coracana*), a low yielding but drought resistant type of finger millet known as the ‘famine crop’ (Lowson and Sahini 1963), was a basic staple and alternative to rice. These rainfed cropping systems could be relied on to provided a means of subsistence, even in years where there was insufficient rainfall to cultivate an irrigated crop.

A **B**

Plate 4.2 A and B – *Chena* land preparation (A) and cultivation (B), Maduragama village, *maha* 2000/2001

Chenas were typically cultivated for 1-2 years; until soil fertility began to decline and weeds began to take over. There after, they were left fallow for 10-15 years for the jungle to re-grow and restore soil fertility. Such *chenas* provided food early and then throughout the season in addition to acting as an insurance against failure of the irrigated crop (Tennekoon 1974). Furthermore, each villager had access to common jungles around the village to cultivate *chenas*, but not all had access to irrigated lands. Under traditional subsistence conditions the practice was also very sustainable. However, with increasing population, fallow periods have been reduced to as little as 1-2 years. The permanent loss of cover also accelerates siltation of downstream tanks.

4.2.3 Homestead cultivation and livestock

Homesteads were concentrated in the *gangoda* (section 4.1.2) beside or below the tank bund where they could benefit from elevated ground water levels or micro-irrigation. Some of the homestead crops are: lime (*Citrus* sp.), jack fruit (*Artocarpus integrifolia*), pepper (*Piper nigrum*), coconut (*Cocos nucifera*), mango (*Mangifera indica*), Papaw (*carica papaya*), banana (*Musa sp.*), breadfruit, areca-nut, betel vine (*Piper betel*), yams, *cassava* (*Manihot utilissima*) and sweet potato (*Ipomoea batatas*).

Larger ruminants, water buffalo and cattle were traditionally the most important livestock in Dry-Zone villages. Both were used for draft purposes; buffaloes to plough the rice fields while cattle were mainly used to pull carts. Milk consumption did not develop as a habit as it did in south India. Also the local cattle were hardy varieties suited to dry-land conditions, but producing very low milk yields. This was compounded by a husbandry system which relied largely on turning animals loose to forage for themselves in fallow rice fields, the tank-bed and abandoned *chenas*. Most small-holdings were therefore geared towards subsistence, with much of the economic contribution recorded in national statistics, coming from larger commercial private sector and state herds. For the small-holder, livestock were most important as capital assets for emergency sales in times of extreme difficulty (Wickremeratne 1985).

Section 2. Social and livelihood characteristics of the intervention villages

4.3 Introduction

In the following section, I summarise the main social characteristics of the six intervention villages where the two phases of action research took place. Thereafter, the main focus is on the five villages located in the Giribawa research area (Figure 4.2), which were the subject of a longitudinal household livelihood survey (Chapter 3). Further details of the preliminary work in Anamaduwa and a second cascade near Galgamuwa (Danduwellawe), are presented in a series of working papers (Murray and Little 2000a – 2000b).

The principle purpose of this analysis is to assess relative levels of poverty, in order to gauge who might benefit most from this type intervention. Secondly, having established a need, to assess capacity for effective collective management of enhanced fisheries in commonly-owned village tanks. Internal poverty assessments are based on the outcomes of wealth ranking (Chapter 3), and a range of other indicators are used to compare villages located at different positions of the watershed with different caste designations.

Basic information was collected during preliminary PRA work, e.g. using time-lines, key informant interviews with elder-villagers, social maps etc. (Chapter 3). However, more meaningful insights into social issues only came with increasing familiarity and candid exchange between villagers and researchers, i.e. during regular fortnightly household visits over the course of a year or longer.

4.3.1 The research areas

Although the two research areas were only some 30km apart, there were marked environmental and social differences between the two sites, some of which have already been described in Chapter 2. Anamaduwa, which is located closer to the populous hill country (Chapter 1: Figure 1.2), has been more intensively re-settled than Giribawa. Consequently, most of the jungle which formally separated *purana* villages has been replaced with plantation and secondary scrub. Though the trend is the same in Giribawa, the process is less advanced and there are still extensive areas of more intact jungle in upper-watershed areas. These are effectively buffer-zones in the re-colonisation process, where villagers remain subject to the depredations of wild animals. The greatest risk comes from scattered herds of wild elephants; this on-going conflict severely limits the cultivation strategies available to villagers (section 4.3.11).

Villagers in both the research areas have benefited from labour opportunities and / or access to land under nearby major irrigation developments. Giribawa borders on system H of the accelerated Mahaweli Development Scheme (Chapter 1), while the Anamaduwa villages have access to the Radavi-Bendi Ela anicut (river diversion) system and a number of other minor reservoirs located close by.

The Anamaduwa Divisional Secretariat (DS) benefited from substantial infra-structural development under Governments *Gam Udava* (‘village-awakening’) in the late 1980’s (Chapter 3). The project which was directly influenced by the Nationalist *Sarvodaya* movement (section 4.1.7) resulted in the construction of a new town. This brought greatest benefits to patrons of the ruling party, leaving the area deeply politicised and prone to some of the worst recent episodes of electoral violence in the country.

4.3.2 The villages

Some general characteristics of all six intervention villages (phase 1 and 2) are summarised in Table 4.1 and Table 4.2while Figure 4.2 shows the geographical distribution of the five villages located in adjacent watersheds of the Giribawa area. The six villages fell into three size categories: (1) GUR and IMK >100 households, (2) LHG and MAD >40 households (3) GBW, SER and ULP >10 households.

The two smaller groups of villages, i.e. containing around 10 – 60 households were settled much more recently than the larger *purana* villages (Table 4.1). The former villages are located on more marginal lands around radial and lower-order axial tanks in upper-watershed areas. Formally, settlement was limited according to water storage capacity within the PC, though this constraint has been progressively eased through tank rehabilitation programs along with increased off-farm labour opportunities. Estimates of *per capita* water availability (Table 4.1) are based on all the tanks in each PC (Murray 2004b, Appendix 16). Water availability remains highest in the PCs with the largest and deepest axial tanks, regardless of settlement age. Availability in GBW is exceptionally high at 5541 m^3/person, suggesting that there is considerable room for expansion of this village. Its current low population level is probably due both to its age, it was settled only 25 years ago, and livelihood limitations imposed by its remote position.

Table 4.1 Physical and social characteristics of intervention villages in Giribawa and Anamaduwa research areas.

Village[1]	ULP	MAD	LHG	GBW	IMK (SER)	GUR
Research area[2]	AMD	GIR	GIR	GIR	GIR	GIR
Watershed location	Upper	Upper	Upper	Upper	Upper	Lower
Age of village	50-60	50-60	110-120	25	>200 (30)	>200
No households	10	51	47	25	106 (11)	119
Population	62	227	190	125	426 (71)	439
Mean Occupancy	6.2	4.5	4	5.2	4	3.7
No radial tanks	2	4	1	2	14	3
No axial tanks	0	2	1	1	5	1
Water-spread (ha)	2.83	9.18	13.56	8.42	15.58	28.83
Water (m^2) / person	457	404	713	674	313	643
Water (m^3) / person	677	550	1153	5441	2308	1276
Km to metalled Rd	2	2	0.5	9	3	1
Km to service centre	5	3	1.5	9	4	1.5
Intervention phase[3]	P1	P2	P2	P2	P1 & P2	P1 & P2

[1] ULP = Ulpathwewa DDW, MAD = Maduragama, LHG = Lokahettiyagama, GBW = Galenbindunewewa, IMK / SER = Ihala Maradankadawala (Serugas) GUR = Gurulupitigama
[2] GIR = Giribawa divisional secretariat, 3 Anamaduwa divisional secretariat
[3] P1 = Phase 1, P2 = Phase 2

Table 4.2 also shows the extent of the tank resources belonging to each community; the overlay of physical access and social boundaries are central to the notion of the '*purana complex*' (section 4.1.8). The figure clearly shows that the populations around the longer settled and largest tank assemblages are predominantly *Goyigama*. Lower-caste villages tend to be concentrated in upper-watershed areas, with fewer and smaller tanks and lower population sizes. GUR, a village of *Paduvua* (palanquin bearers), was one of the few sizeable low-caste communities settled around a large lower-watershed tank.

Table 4.2 Caste characteristics of village communities in the Giribawa and Anamaduwa research areas

Caste	Traditional role	Caste hierarchy	Map Code[1]	Village[3]
Goyigama Radala	Land owner / cultivator	Highest	GR	MDW
Goyigama	Land owner / cultivator	High	GO	**IMK/SER** HET PMK GIR WAR. KBW
Achari (Naide)[2]	Blacksmiths	Middle	BS	**LHG**
Walawe vedane[2]	Horn players / ceremonial attendants	Middle	WV	POT
Berava[2]	Drummers	Middle	DR	(Anamaduwa)
Paduvua[2]	Palanquin bearers	Middle	PB	GUR
Badahala(Kubal)[2]	Potters	Lower	PO	**ULP** (Anamaduwa)
Rodi[2]	Basket weavers	Lower	BW	(Anamaduwa)
Rada[2]	Dhobi / washermen	Lower	DB	**GBW** KHW
Kuthadi	'Gypsies'	Lowest	GY	**MAD** RLP

[1] See Figure 4.2 [2] Service castes [3] Intervention villages in bold

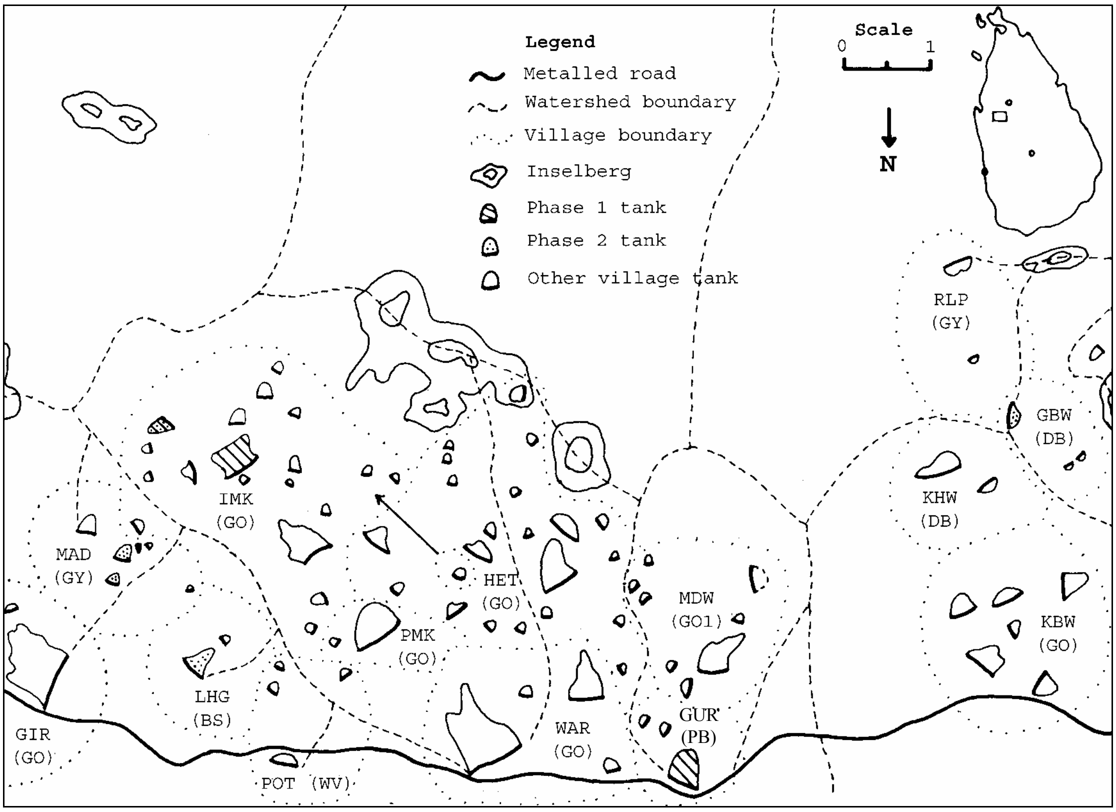


Figure 4.2 *Purana* complexes and their caste designations in the Giribawa research area (caste codes in brackets – see Table 4.2)

Although it was not possible to accurately distinguish between the different *Goyigama* tiers (*wanchi*), one (non-intervention) village neighbouring GUR, Madawalagame (MDW), appeared to have higher status than the rest. An elderly '*arachchi*' (former leader of the *variga* court) extant in this village claimed descent from officials of the Kandyan Kings era, a claim support by the neighbour GUR village. Marriage here was entirely endogamous, villagers refusing to inter-marry even with other local *Goyigama* communities; hence the *variga* here was still entirely homogeneous. The community was also unusually well endowed with extensive local and external land holdings in the Mahaweli H system.

Three other *Goyigama* communities in middle / upper-watershed areas; HET, PMK and IMK have also retained largely homogenous *variga*, while those in lower-watershed areas; GIR, WAR, KBW were more mixed. Further details of the social makeup of each of the intervention communities, including those of lower-caste designation, are discussed in the next section.

4.3.3 Social characteristics and development history of the intervention villages

A description of the social composition and recent development history of the six intervention villages is discussed in the following section. The villages that participated in the phase 1 trials are described first, followed by the phase 2 villages (Figure 4.1). Social maps of each of villages in the Giribawa research area are presented in Appendix 28.

Lokahettiyagama (LHG):

Two brothers and their families first settled near what was then a semi-derelict tank around 110-120 years ago. KM Ranaide, the 89-year old son of one of these settlers, is still living in the village. The number of households rose to five (approx. 30 persons) by 1950 and to 45 (190 persons) at the present time. This substantial increase was supported by a major restoration of the tank in 1960, followed by further expansion with the support of an international NGO in 1990. Several years prior to the first restoration, a major flood forced the existing households to relocate to safer higher ground below and to the side of the tank. A second small radial tank still lies semi-derelict and is effectively private, being used by one family for occasional supplementary irrigation.

After 1960 the vacant plots in the upper part of the village were settled by 7-8 households from a small nearby town (Maho) who married and purchased housing plots from the lower-village. These settlers in turn invited other relations to join them. Although some incomers gained paddy lands when the tank was expanded, most of the more productive *purana wela* (old field) was retained by the 'lower-village'.

Many in the lower-village expressed a sentiment that the village was 'much more cohesive' prior to the incomers arrival, and that this remains the main cause of social division to this day. They cited high illiteracy rates and a tendency to drunkenness as indicative of a low premium on education and self-betterment by the 'new-comers'. This in turn contributed to other anti-social tendencies, including a reluctance to participate in village institutions, or to respect many normative community rules. An example of the latter claim relating to the tank fishery is described below.

In turn the incomers, particularly the youth, felt alienated. Many were now second or even third generation and although they belonged to the same *Achari* caste as the established community, they were still considered by them to be *pita variga*. They were also clearly economically disadvantaged. Lack of access to productive lands within the village means they were also heavily reliant on agricultural labour under nearby perennial tanks as well as within the village. Members of at least eight households in the lower-village enjoy salaried public and private sector or professional jobs, while only one public servant lives in the upper-village. This lower-village is also much closer to a new metalled road giving them greater access to local services (see Figure 4.2 and Appendix 28: Fig A28.2).

The principle underlying cause of the social division appears to be one of status and power. The 'incomers' lack the confidence and voice to articulate their feelings at public forums, and consequently, some of their number, particularly male youth, behave in ways that are deemed inappropriate by the lower-village. The conflict of interest between the two groups is clearly expressed in relation to the tank fishery, which is exploited on a subsistence level almost entirely by upper-village households adjacent to the tank. For reasons of social taboo associated with subsistence fishing (Murray 2004a) the 'lower-villagers' expressed little interest in participating themselves but as indicated above, still to some degree felt aggrieved at not being accorded any reciprocal benefit. Instead ‘lower’ villagers prioritise bathing leading to regular seasonal conflicts with youth from the ‘upper’ village.

In both LHG and MAD, a project sponsored by an international NGO, which terminated 5 years earlier, funded construction of a number of simple, small but permanent houses and several agro-wells. These physical interventions ran alongside health and education social programs targeting youth. LHG villagers were encouraged to cooperate with the neighbouring lower caste village of Potanagama (POT - Figure 4.2) in planning and mobilisation of local resources. Today the villages still share access to water for bathing and domestic purposes. It was hoped that introducing managed stocking-enhancements in the village might replicate this cooperative progress.

Maduragama (MAD):

Two villages, Maduragama (MAD) and a second non-intervention village, Ralapanawe (RLP), were settled by gypsies (*Kuthadi*); MAD in the 1950’s and RLP some 20 years later. This was the lowest caste group encountered in the study, where most households had changed their family names to titles less indicative of their low status (the same practice was also reported a lesser extent in GUR; family names alone were therefore a poor indicator of status in all but higher-caste villages). Because of sensitivity surrounding the caste issue, there was greater reliance in MAD, on key informants from neighbouring IMK and LHG. The Maduragama villagers were still considered very much as outsiders by all the neighbouring villages, some of whom also blamed them for an influx of more recent arrivals. The RLP community, located alongside other lower caste communities (blacksmiths and dhobis), also showed evidence of similar marginalisation; the two groups share access but segregate bathing to different parts of Ralapanawe, a large perennial tank, during the dry season.

When 75-year old W.A. Thomasinghno came to Hangogamawewa (HNG - one of the three main tanks in the village) to begin a settled agricultural life 55 years ago, only 3 other families were already living there. Other villagers with more settled backgrounds came from three locations within a 35km radius and more recently (around 1985) 6 internally displaced households from war affected areas around the east coast town Trincomalee settled. These families still retain some of their old paddy lands and return seasonally to Trincomalee to oversee its cultivation.

Although the village is relatively heterogeneous in terms of origin, most villagers that were not already related have since become so by inter-marriage. This endogamy is to a large extent forced on the village by its low status, but it also corresponds with a cohesiveness and self-sufficiency that was admired and envied by several key informants from LHG. The relationship with the adjacent higher-caste *Goyigama* community in IMK was tenser, as evidenced by the exclusion of MAD from their own village map (Appendix 28: Fig A28.1) and even a reluctance to give us directions to MAD, when we first came to the area.

Two of the village's main tanks and their command area belong to the local temple, to which the cultivators pay the equivalent of roughly one quarter of the value of their crop. Construction of the smaller KRB tank was initiated by Thomasinghno in the 1950's. This was later expanded with state assistance, whereby it effectively changed from a private to communal resource. Nevertheless, Thomasinghno and his son still receive occasional gifts of fish from the tank which formerly belonged to him.

Galenbindunewewa (GBW):

GBW was settled only 25 years ago, when an ancient tank in an upper-watershed area was reclaimed from the jungle. This followed construction of a modern track which remains un-surfaced and difficult to pass during the monsoon season. All the settlers originated from Ramabwewa, a *purana* village (>150 years) of low cast dhobi's (*Rada*) in the adjacent catchment. Consequently, all 25 households originate from the same *variga*. Other villagers from Rambawewa settled slightly earlier around the neighbouring Kahatagaswewa tank (KHW) and relations are still strong between all three sub-villages, one informant in Ramabawewa stating that 'although we have three settlements we still feel as one village'. This is evidenced by the shared bathing activity and fishing activity which takes place between the GBW and KHG communities. By contrast, there is much less interaction with other low-caste communities to the south including Ralapanawe (Figure 4.2).

This location amid a still lightly settled jungle area made GBW the most remote village in the survey with many implications for livelihood outcomes. Although, all middle to upper-watershed villages in the Giribawa area suffered from wild-elephant incursions, none were as severely affected as GBW, which is adjacent to Wilpattu National Park. There are up-to 15-20 animals in each herd (smaller groups are the norm in the more populous areas) and housebreaking and crop raiding, are one of the villagers' greatest problems (section 4.3.14). This effectively limits cultivation options to home-gardens and paddy under the tank as remoter *chena* plots dispersed in jungle areas are too difficult to protect; often failing even when more 'elephant resistant' crops, were planted (section 4.3.11).

Of all the villages, GBW is also furthest (9km) from its nearest service centre and weekly market (*pola*). This, and the village's position almost 20km equidistant from the two nearest major irrigation systems (Appendix 1), also made it more difficult to engage in casual seasonal labour or to procure salaried positions, than in the other villages. During the survey, only four households laboured seasonally under the Rajangane system and no GBW villagers owned or leased paddy holdings outside the village. Members of six other households made longer migrations to Anuradhapura, Kurunegala and Colombo cities for 'coolie' work; mostly in paddy mills and construction. These migrations took place during the dry months (Aug - Sep) when their village harvests are completed. As the survey progressed it became apparent that more than half the households in the village were also involved in illegal timber-felling activity in surrounding forests.

Unlike the larger and longer settled villages every household in GBW owned some land, at least 0.2ac, under one of the village tanks; either GBW^{t} (10ac command area - CA) or Konewewa (5ac CA). Cultivation under a third radial tank, Udawewa (6ac CA), had ceased when the bund breached 15 years earlier.

Gurulupitigama (GUR):

GUR, the largest village in the survey is located in a lower-watershed area, adjacent to the middle section of the left bank canal of the Rajangane major irrigation reservoir (Appendix 1). The lower half of the command area under the main village tank has received irrigation water from this source since the early 1960's, freeing tank storage for other uses. GUR is also strategically located only 1.5km from Warawewa the nearest service centre, which although small has a range of retail, engineering and fuel outlets. The unsurfaced track running through GUR links up with the main Puttalam to Anuradhapura road, 12.5km to the east. Although it is currently only metalled as far as Warawewa, there are plans to complete the remaining section in the near future. Some 20 houses in the lower part of GUR had already been connected to the mains electricity supply, though none of the other villages in the survey were electrified as yet (Figure 4.1).

Social cohesion appeared to be very strong in GUR, despite its large size. Its single *variga* and low-caste status, relative to neighbouring PCs, were again important factors. Strong and charismatic village leaders were also important; RDB Tikira (age 60), an ex-farmers organisation (FO) president of medium wealth, was one of the most influential people in the village, to whom people turned for internal dispute resolution with the support of executive members of other village institutions.

The main social division in this village was inter-generational, of which there were several manifestations. The FO organises separate tank *Shramadana* events (collective public service activities – section 4.3.10) to those of the *Samurdhi* group, in order to encourage participation of all water users in the village, rather than just the poorer welfare recipients. These take place once every 2-3 months and approximately 95% of households were reported to be regular participants. Non-participants included six wealthy households, who although economically influential, were criticised because of their failure to engage in collective communal activities. While the FO leadership were clearly acting in good faith in organising separate events, their policy created some resentment, particularly amongst the youth. During the previous year the FO president had been responsible for collecting the names of 84 youth who had defied a fishing ban. The dispute was resolved internally after the youth agreed to clear the tank bund of over-grown vegetation, rather than involve the police. Most accepted this as fair recompense.

Nevertheless, this and other similar differences provided an incentive for the same group to establish their own break-away Death Donation Society (DDS – section 4.3.10). This occurred at the instigation of a charismatic 24 year old male *Samurdhi* extension officer living in the village, one of the main leaders and spokespersons for the group. Many households of low median age, including a sizeable proportion of the landless or land-poor, also felt that membership of the established DDS was too costly. After two years, the new society was already almost equal in size to the original. The membership of both societies incorporated the entire village, while 14 households belonged to both societies.

Three international NGOs were also active in the village at the time of intervention. They had sponsored a range of activities over the previous five years including small livestock and perennial crops micro-projects, agro-well construction, tank rehabilitation and road improvements.

Ihala Maradankadawala (IMK), Serugaswewa (SER):

IMK is of comparable size and age as GUR, but differs in it's mid to upper-watershed location, its large number of tanks and high-caste *goyigama* status. Amongst all the villages, IMK was also politically the most polarised and the attendant problems of patronage had resulted in marked internal divisions. Unlike the other villages, these appeared to persist beyond election periods. This made collective interventions in the village much more problematic, consequently, an attempt was made to shift emphasis to the smaller sub-population settled around SER.

SER tank is effectively under control of five households; three living beside the tank and two from a small neighbouring PC, Gampola. These farmers collectively own the tanks command area. Other adjacent households put the tank to seasonal use for bathing, livestock pasturing / watering and occasional fishing, but pressure for these uses is relatively low, due to the availability of other nearby PC tanks which are less seasonal.

Control of one of these tanks, Welikandawa (WEL) has been consolidated by a single household who are staunch supporters of one of the main Sinhalese political parties. Through this patronage they had also obtained considerable financial support towards the tank's restoration. By contrast, the situation under SER is far less polarised. A respected elderly farmer, living close to the tank, took informal responsibility for co-ordinating its management.

Ulpathwewa (ULP):

The two smallest intervention settlements; ULP and SER (10-11 households) are both geographically discrete populations around radial tanks on the periphery of larger communities. The SER population belongs to the same *variga* as the IMK base-tank community, and can be considered as a separate *gangoda* (section 4.1.2). By contrast, ULP was associated with a much larger community settled around an adjacent axial tank (Pahala Diulwewa - PDW) and this assemblage was unique in being the only example of mixed-caste community encountered in the research areas. ULP are low-caste potters (*Kubal*) while PDW were high-caste *Goyigama*. The unusual situation arose because of the simultaneous re-colonisation of the area by the ancestors of the two groups about 90 years ago. In ULP, these were three brothers who constructed the first small tank on the site. Today there are 10 households in ULP, all part of a single extended family, and 67 households in PDW. There is minimal interaction between these two highly polarised caste groups despite their proximity.

All the ULP households were considered poor according to key informants in PWD. All live in temporary houses and had low levels of literacy; adjudged by these indicators, they were probably the poorest intervention community. They have access to irrigated lands only under their own highly seasonal tanks, and consequently, have a high reliance on off-farm agricultural labour. However, they had recently been fortuitous in attracting aid from an international NGO to renovate both their tanks, including costly de-silting (Chapter 2). Unfortunately the method of delivery for this support, which required negligible farmer participation, had also served to re-enforce a strong dependency culture in the village. This subsequently made it much more difficult to pursue a subsistence-based intervention designed to foster self-reliance.

4.3.4 Wealth ranking

Wealth ranking was carried out during a base-line phase in each of the five phase 1 and 2 intervention villages in the Giribawa area. SER and IMK are distinguished from each other for the purpose of this analysis, although part of the same community. Outcomes of the wealth ranking exercises were also plotted on the social maps reproduced in Appendix 28.

The proportion of households in each wealth category were relatively similar in all the villages, overall with 13, 37 and 50% of households in better-off, medium and poor wealth ranks respectively (Figure 4.3). Better-off households varied least (9-16%) while almost 50% households, the highest proportion, were assigned a medium rank in both GUR and LHG. This suggests that location may be more significant to wealth outcomes than caste status *per se* as both are located close to metalled roads and near to service centres. However, as noted earlier, it also appears that low-caste communities are more likely to be forced into remoter upper-watershed sites.

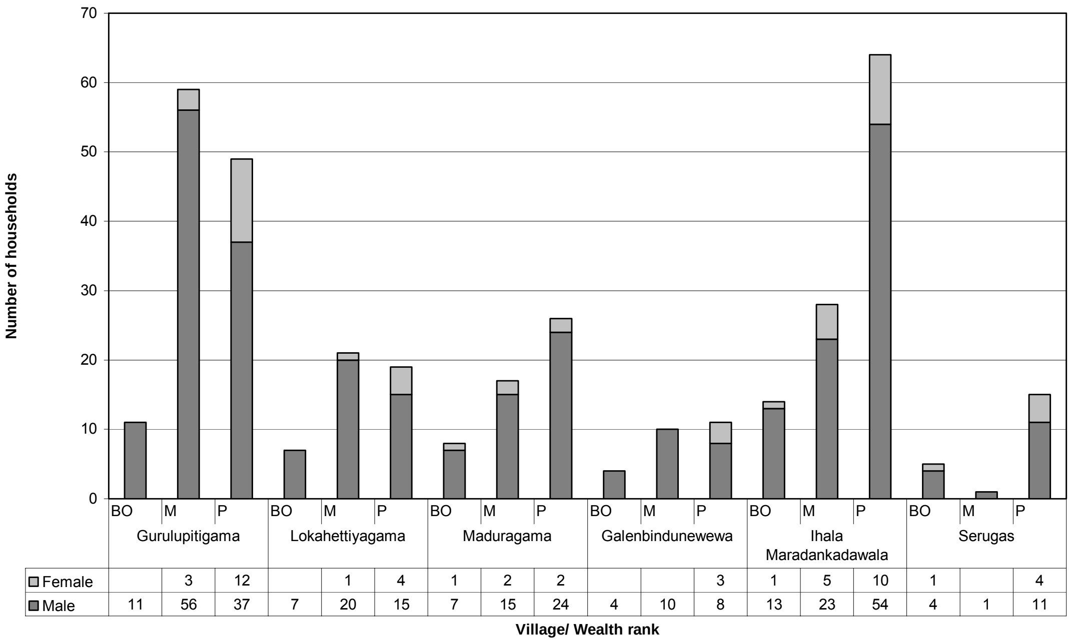


Figure 4.3 Frequency of households belonging to different wealth groups by gender of household head in five intervention villages (wealth ranks: BO = better-off, M = medium, P = poor), 1999 - 2000

The number of female headed households averaged 13.3% overall with relatively uniform proportions in each village. Most of these households (71%) were classified as poor; only in MAD was there a more even distribution between all wealth groups. 'Better-off' female household heads tended to be separated from their husbands due to long-term labour migration commitments, e.g. police or army postings. Most of the 'poor' female headed households had been separated, deserted by their spouses or widowed. Female labour migration was also responsible for most of the single-male headed households which constituted 6% of the total population. These 'absent' women worked mainly as overseas housemaids or locally in the garment industry. Although receipt of remittances was cited as a potential wealth indicator (Chapter 3), this is likely to depend very much on the type of migration involved. Bohle and Mayer (1998) found that the trend towards female labour migration can have particularly negative consequences for family cohesion; a critical observation, given that the family remains the fundamental unit for economic and social support in Sri Lanka. In the Giribawa area, 6.3%, 8.4% and 12.3% of households in LHG, GUR and IMK (respectively), had female members working overseas. The lack of such absentees in the smaller villages, suggests that the adverse social consequences described above may be worse in larger, more affluent villages, i.e. because households in these villages are more likely to afford to the initial costs of obtaining such positions.

In the next sections, I will outline some broad differences in livelihood characteristics between the Giribawa villages. Thereafter, I will use the wealth strata described above to compare and draw conclusions regarding the impacts of water-shed location and social status on poverty characteristics.

4.3.5 Livelihood profiles

Figure 4.4 is based on citation frequencies of the main income generating activities for each household. The data was collected from key informants during the wealth ranking exercise. Frequencies ranged from 1-5 activities per household. Agricultural production and agricultural / coolie labour were the most frequently cited categories overall. The relative importance of 'on-farm' agricultural production is greatest in GBW because of its remoteness. GBW and SER which are closest to primary areas of scrub jungle also show the greatest dependence on timber and non-timber forest product (NTFP) extraction. These activities include: illicit timber felling, hunting, charcoal production, wild honey, aquatic and terrestrial plant collection.

The number of households involved in livestock production was very low for reasons discussed elsewhere: (1) farm mechanisation and a decline in pasture availability (2) their primary role as emergency collateral, over and above income generation.

The two other most frequently cited activities were skilled trades and remittances. Skilled trades included: masons, carpenters, barbers, mechanics, goldsmiths, blacksmiths and a single baker in GUR; unsurprisingly the highest numbers were in LHG the 'blacksmith' village. MAD also had a high proportion of masons and carpenters. Remittance citations were highest in the larger villages IMK (including SER) and GUR. The relatively high levels in MAD were mainly associated with female employment in the local textile sector.

Up to ten income categories were cited in the larger villages, while the lowest frequency (6 categories) was in GBW. Again this was probably due to the lack of off-farm income opportunities imposed by the village's remoteness.

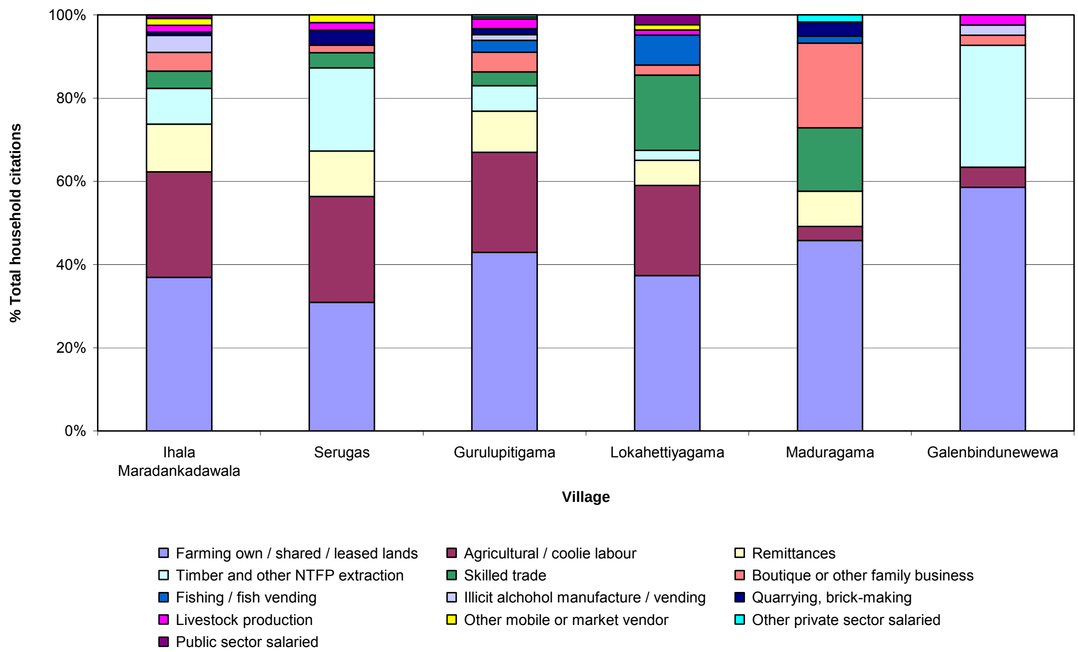


Figure 4.4 Occupational characteristics of the intervention villages in the Giribawa area, 1999 - 2000

4.3.6 Household size

Village-wise household occupancy distributions from the baseline survey, are summarised in Figure 4.5. There was no clear difference in occupancy between wealth groups within villages (ANOVA: F (2/33) = 3.02; p = 0.05), but significant overall differences between the villages (F (4,333) = 6.08; p <0.01). Results showed no significant interaction between the two variables (Figure 4.6). Tukey's test revealed that GBW had significantly higher overall occupancy than GUR, IMK and LHG, while MAD was significantly higher than GUR (p < 0.1). These results correspond with mean occupancy levels ranging from 3.7 – 4.1 persons in GUR, IMK, and LHG to 4.5 – 5.2 in MAD, GBW. Higher occupancy levels therefore appear to be indicative of increased poverty levels in lower-caste / upper-watershed villages.

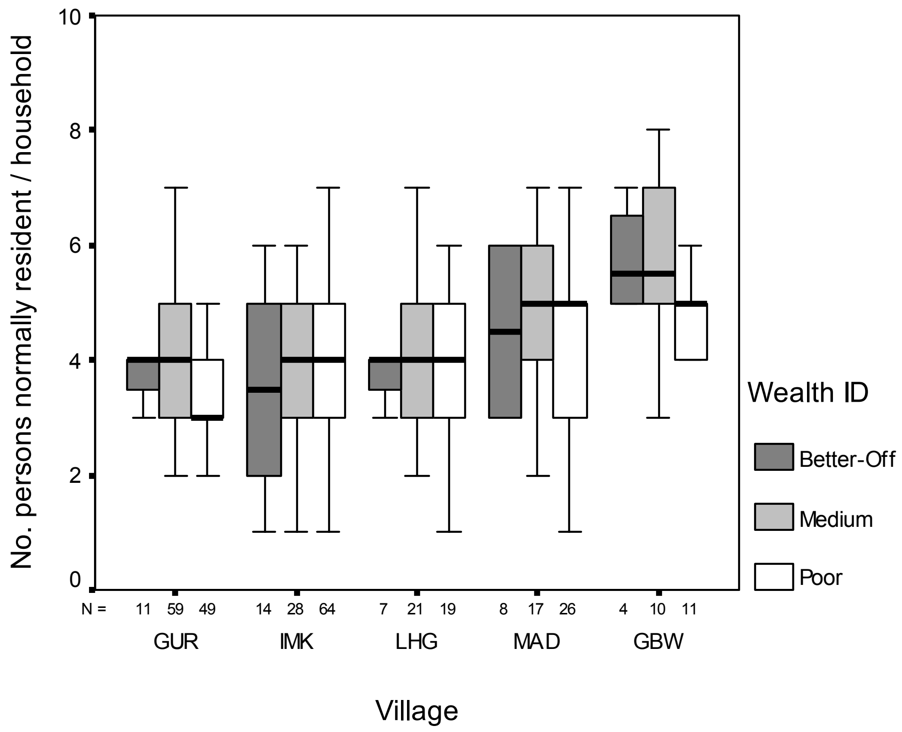


Figure 4.5 Box plot showing percentile distribution of household occupancy levels by wealth in five intervention villages (N = No. households per village and wealth category), 1999 - 2000

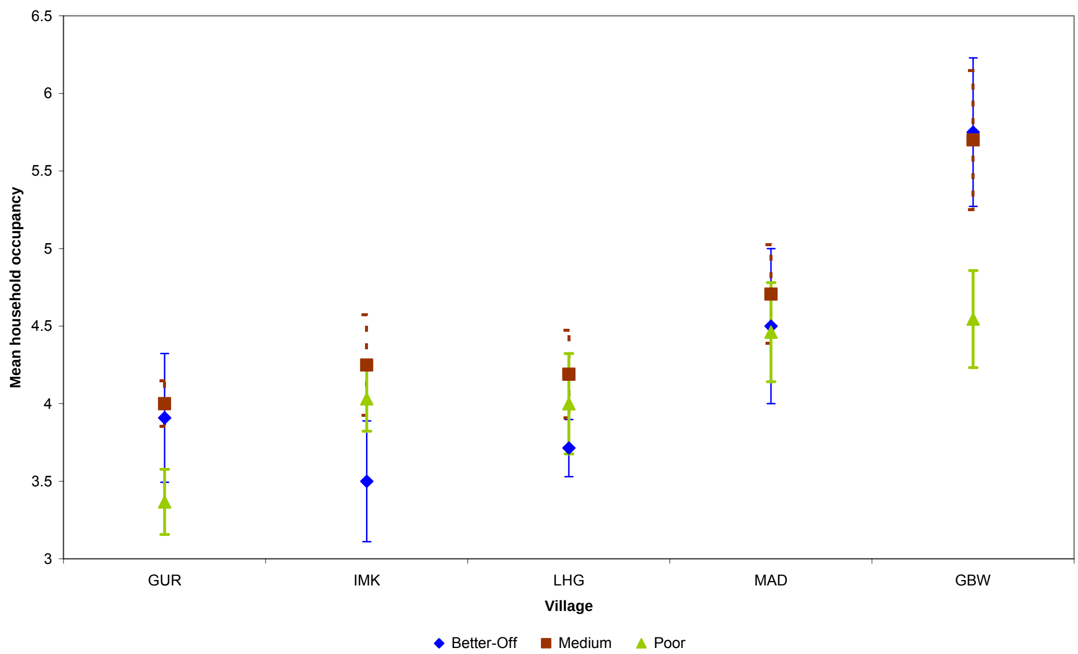


Figure 4.6 Mean occupancy levels with standard error bars, by village and wealth rank in five intervention villages, 1999 - 2000

Most of the data presented in following sections is based on responses from 41 households involved in the wealth stratified longitudinal household survey implemented in GUR, LHG, MAD and GBW.

4.3.7 Literacy and poverty

Educational status was one of two main indicators employed in the wealth ranking exercises (together with housing status). Consequently, it was anticipated that literacy levels should correspond broadly with wealth status. An appreciation of functional literacy characteristics was also useful in deciding how to present the feedback used in adaptive learning exercises (Chapter 3).

Figure 4.7 is a summary of literacy levels, based on self-assessment, relating to a total of 190 members from 41 households aged 10 or above, cross-tabulated by gender, wealth rank and village. Data relates to the households sampled from the four villages in the longitudinal household survey, i.e. excluding ULP, IMK and SER (Chapter 3). Household members were placed into one of three groups; illiterate, semi-literate or literate. The intermediate group; functional literates, consisted of those able to read simple text and to sign their name.

Results indicate the lowest literacy levels for both sexes, amongst poor households in all villages except LHG, where the trend is reversed. This is almost certainly due to the polarisation of the village described above, which made this question particularly sensitive. Experience of working with these same poor households in various PRA and adaptive-learning workshops also ran counter to this finding.

Literacy results were subjected to ANOVA, this time with three independent factors: gender, wealth rank, and village. Results indicated a significant gender difference ($F_{(1, 25)} = 0.021$; $P < 0.05$.), which was relatively marginal amongst those who fully literate; 64% and 60% of males and females respectively, but more marked between those entirely illiterate; 8% and 17% of males and females respectively. More of the latter group also came from the poorest wealth ranks. Although the LHG result precluded significant outcomes on the other factors, Figure 1.6 shows that poor men and women in GBW had the lowest literacy levels overall, with only 25% and 20% fully literate respectively. The results also showed a higher mean age (41.7 years, S.D

10.1) amongst the illiterate population, than either of the literate (37.6 years, S.D 10.3) or semi-literate groups (37.5 years, S.D 10.5). This is consistent with the improved access of the younger generation to primary and secondary education. More marked are the differences between these findings and national averages; in 2001 it was estimated that 90.1% of the population aged 15 and above was literate, comprising 94.5% of males and 89.3% of females (UNDP 2003). In this study only 62% of the sample group were fully literate and an additional 20% semi-literate, reflecting the relative poverty of the Giribawa area.

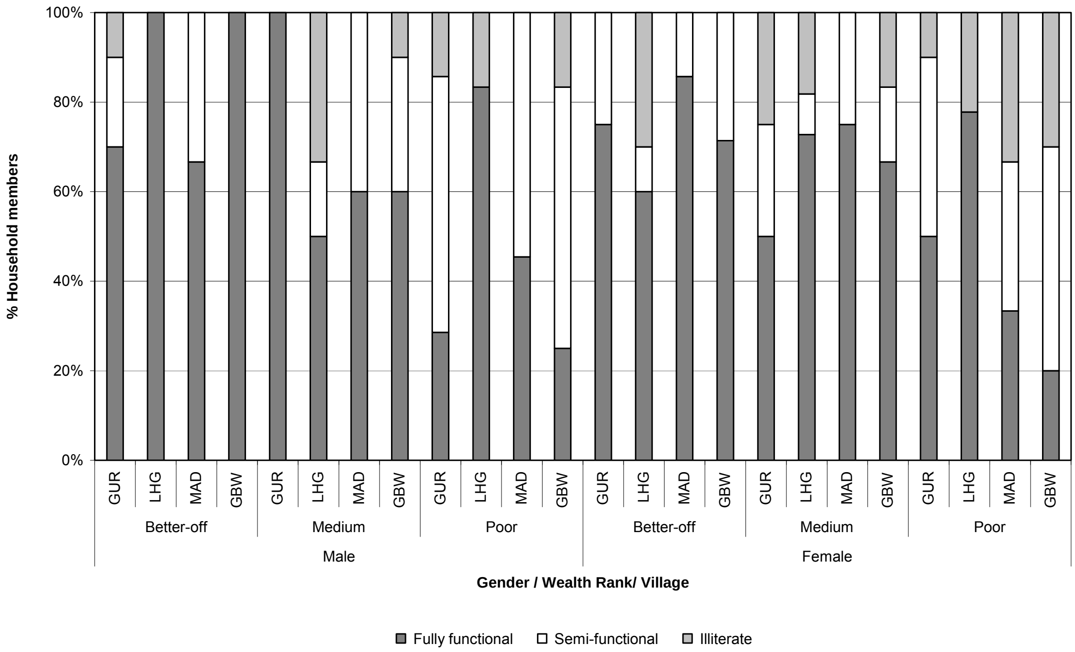


Figure 4.7 Percentage literacy of a sample of households in four Giribawa villages, 2000

4.3.8 Welfare eligibility as an indicator of poverty

The main State welfare benefit, known as *Samurdhi*, is based on an income threshold of Rs 1,500 /month, and consists of a food stamp and compulsory saving component. The later component has, to date, been unredeemable. Eligibility is determined by the *Grama Niladhari* based on information collected by *Samurdhi Niyamakes* (welfare workers). While eligibility might appear to be a useful wealth indicator, *Samurdhi* and *Janasaviya,* its predecessor under a previous regime, are notoriously poorly targeted and therefore of little practical use. This is largely due to patronage; welfare animators are politically appointed and those that did well under the *Janasaviya* regime are unlikely to do well under the new *Samurdhi* system. Consequently, it is estimated that nationally, over 50% of benefits are received by households above the minimum income threshold (Daily Mirror, 2002). Poorer households are also more likely to be excluded because of participation in illicit activities such as timber extraction or illicit alcohol production / retailing, although in many cases they are left with little option.

These observations are reflected in findings from the longitudinal household survey (Figure 4.8). On average benefit levels are highest in the remotest village, GBW and lowest in GUR, with intermediate levels in the other two villages. This is broadly in keeping with the wealth hierarchy suggested by other indicators presented below. However, without exception, better-off households with smaller mean household sizes received higher benefit levels within each village. Despite income-based restrictions, only four of the twelve 'better-off' households in the sample received no benefit (one in each in MAD, LHG and two in GUR), while one of the poorest female-headed household in GBW, who retailed illicit alcohol, was deemed ineligible. Several families who gained preferential political treatment under the '*Janasaviya*' system also found their payments fixed at the historic rate under the new *Samurdhi* system.

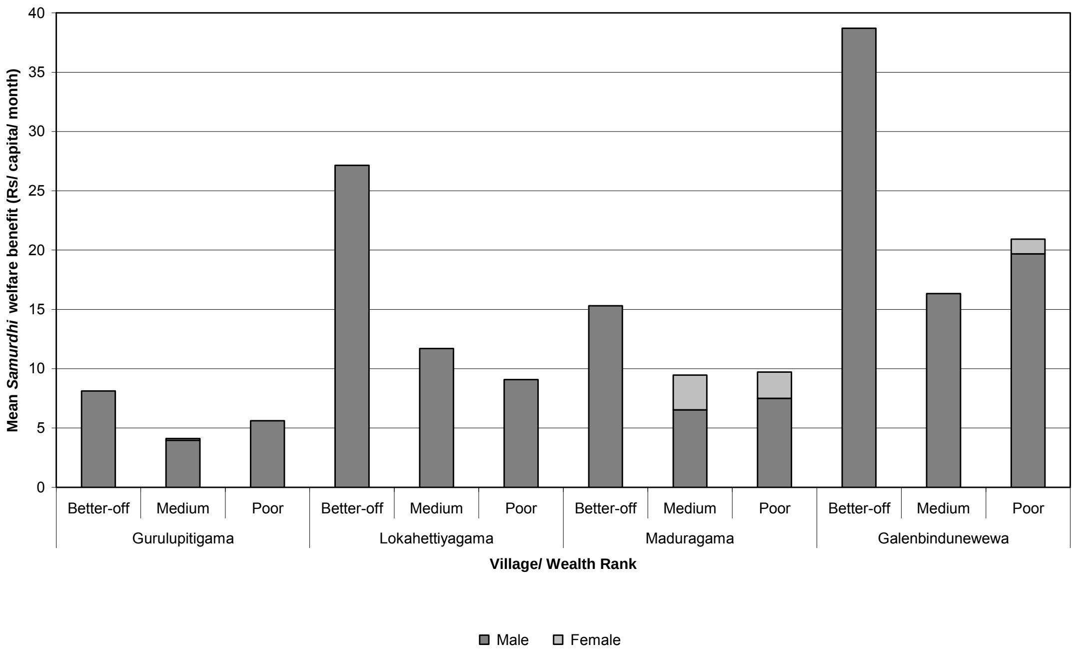


Figure 4.8 Mean monthly *per capita Samurdhi* welfare benefit by wealth rank, gender and village location, Dec 00 - Nov 01

A second though much smaller hardship benefit known as *pinpadi* (poor dole) is available to the very poorest households and appears to be more accurately targeted;

consequently, some stigma is attached to its receipt. Only two households in the current survey collected the benefit, both poorer single-female headed households in MAD and GBW.

4.3.9 'Non-food' and 'protein' expenditure

While household financial data is extremely sensitive and notoriously difficult to collect with reasonable accuracy, most respondents were more ready to reveal expenditure than income details. Figure 4.9 shows mean expenditure over a 13 month period in each village by wealth group. Results are inversely related to the benefit levels described above. GUR spends 5.4 times as much as GBW, with LHG and MAD again recording intermediate levels. The gap between better-off and poor becomes more marked as over-all village expenditure levels increase; in GUR better-off households spend more than five times as much *per capita* as the poor, while they spend only three times as much in GBW.

Even more revealing is a breakdown of how much of this expenditure takes place within the village economy. Internal expenditure accounts for nearly one quarter of the total (24%) in GUR, 16.1% and 12.8% in LHG and MAD respectively and only 6.3% in GBW. In other words, GBW loses out significantly on potential internal multiplier-effects further compounding its relative poverty.

Overall 53% of total expenditure in all villages was on agricultural inputs (seed, agro-chemicals, labour, machinery purchase, maintenance and hire, post-harvest processing). Because of its size and location, considerably more services were available in GUR, including tractor-hire and paddy-milling, than in the other villages. This accounted for a large proportion of the high level of intra-village expenditure. At the other extreme GBW internal expenditure consisted mainly of local inputs to ceremonial events (weddings, funeral, festivals and alms giving), costs of agricultural labour and some house construction. Furthermore, whereas all the other villages had a mixture of general and specialised boutiques selling groceries and household goods, GBW had only one very small boutique which opened periodically to sell lunch packets. Although overall, medical expenses accounted for only 6.6% of total expenditure, the poor in GBW spent 31% of their 'non-food' income on medicines compared to 51% on agriculture. Much of this medicine was used indiscriminately, particularly on the medication of undiagnosed 'fevers' using antibiotics.

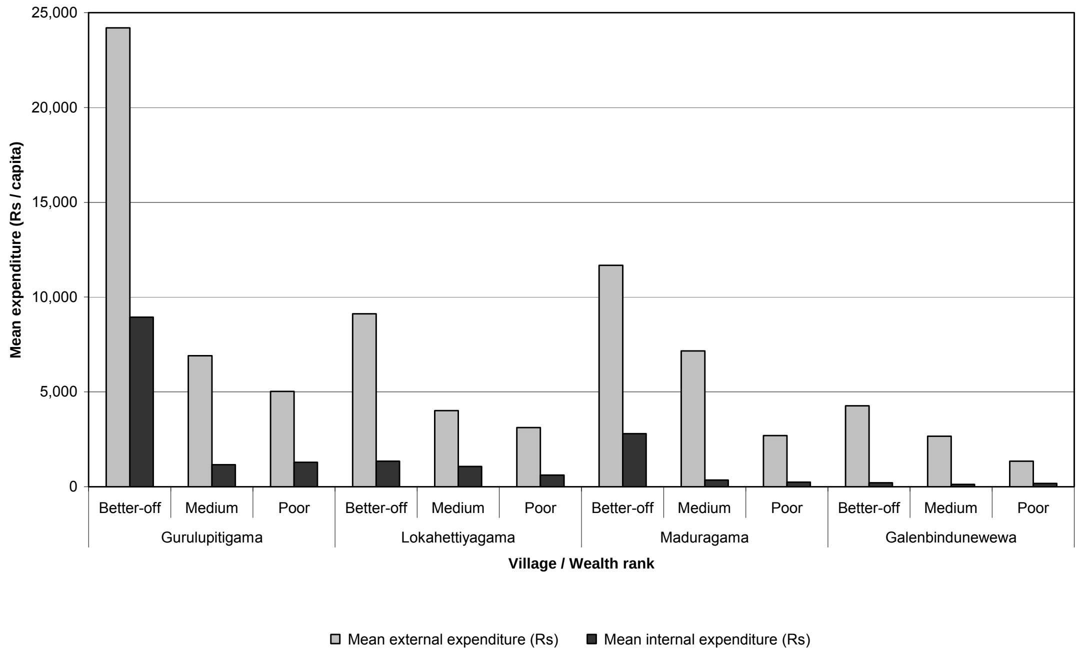


Figure 4.9 Mean *per capita* 'non-food' expenditure within and outside the village economy, Nov 00 – Nov 01 (based on mean occupancy levels over same period)

The inter-village trends discussed above are also broadly reflected in expenditure patterns for fish and its substitutes (Figure 4.10). Fresh inland fish (94% tilapia by value) received the single most expenditure. The proportion was generally higher amongst better-off households, while poorer households were more reliant on subsistence production (Chapter 6). This is also likely to be the main reason for lower overall expenditure levels in the smaller villages, most notably GBW where farmers are much more reliant on their own farm produce and non forest timber products (NFTP).

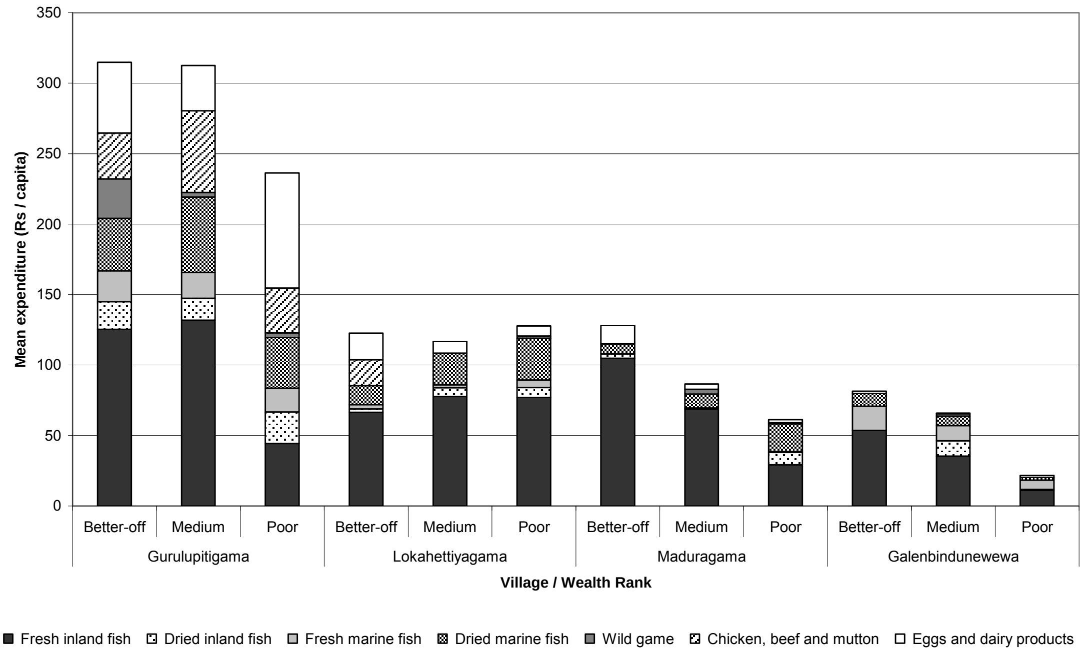


Figure 4.10 Mean *per capita* fish, meat and dairy product expenditure, Nov 00 – Nov 01 (based on mean occupancy levels over same period)

4.3.10 Analysis of community-based institutions

A detailed analysis of existing community-based institutions (CBOs) was undertaken in order to (1) select the most suitable local partner organizations for action research and (2) to understand existing patterns of formal cooperation. Selection criteria included: meeting frequency, attendance levels, how inclusive the institutions were of different social groups and institutional capacity. Data was also collected on: membership boundaries, i.e. how open were institutions to members of neighbouring communities, the involvement of external organizations in implementing and sustaining institutional structures and how the different institutions formulated and enforced rules. Meeting frequency and cumulative attendance levels reported in Figure 4.11 to Figure 4.13 are those of the 41 households in the longitudinal household survey. Results were weighted to compensate for the uneven stratified survey design (Chapter 3).

There were nine different kinds of formally constituted community-based organisations (CBO) in the phase 2 intervention villages (Figure 4.11). The three most active were: the death donation society (DDS), village development society (VDS) and small activity groups (SAG). All of these groups revolved around welfare functions. They differed primarily in terms of the degree to which they were indigenously or externally implemented, and therefore their degree of local autonomy. A brief assessment of these and the other CBOs are given in the following sections.

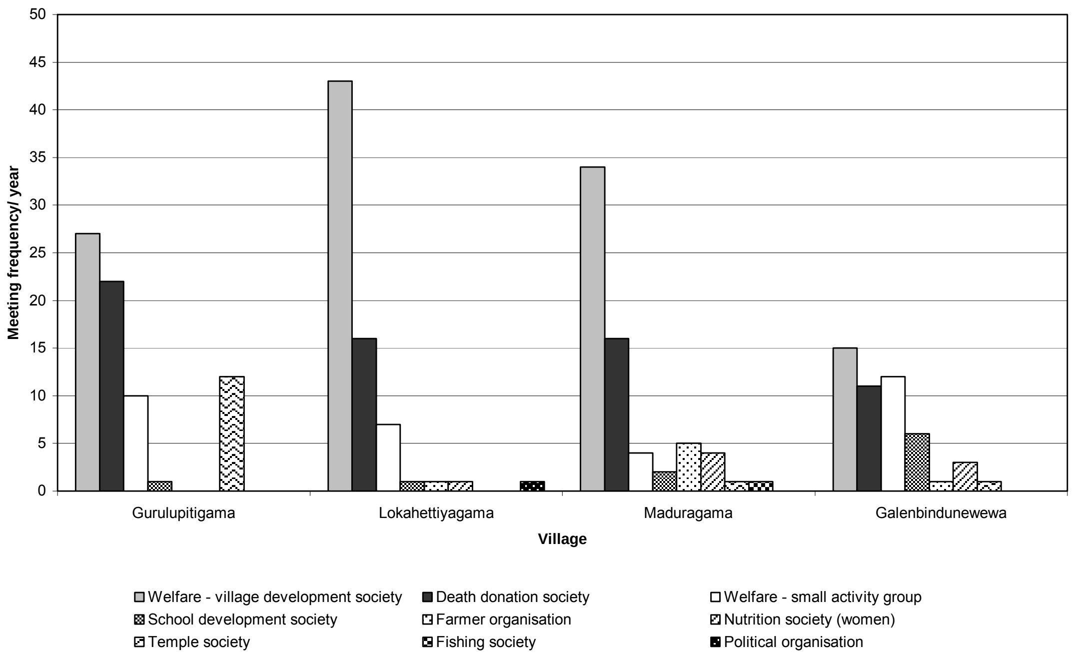


Figure 4.11 Annual meeting frequencies of community-based institutions in four low-caste villages, Dec 00 and Nov 01

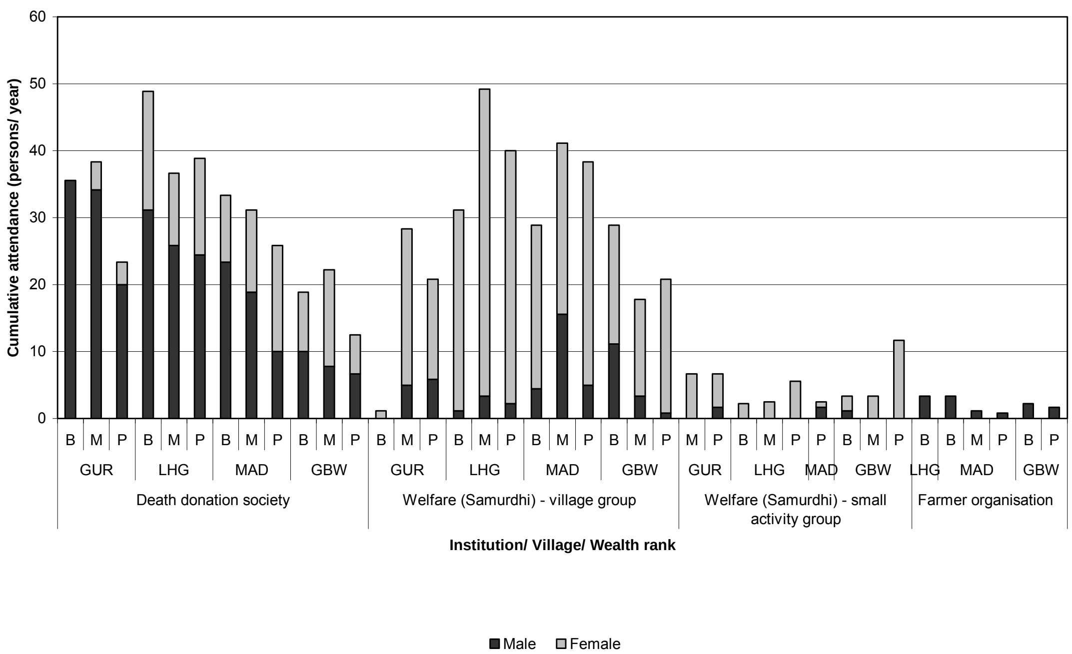


Figure 4.12 Cumulative annual attendance at meetings of selected community-based institutions by wealth rank, gender and village location, Dec 00 - Nov 01 (Key to wealth ranks: B = better-off, M = medium, P = Poor)

State welfare (*Samurdhi*) institutions

In the past, the coupling of collective action and religious merit ensured broad participation by different social groups in a range of mutually beneficial collective activities (*Shramadana*). Just how prevalent this tradition was in the past, and which areas of activity it was limited to, is open to speculation. Nevertheless, over recent decades, there has been a widespread resurgence of a contemporary version of the practice in Sinhalese villages. There are two main reasons for this; firstly the linkage of this and other self-help 'traditions' to the nationalist agenda described in section 4.1.7. Secondly, and perhaps more significantly, participation has also been coupled to welfare eligibility. Contemporary *Shramadana* events incorporate a broad range of public works including weed clearance from public places and simple maintenance of roads and tank bunds. Consequently, the main incentive to participate is financial. All but the very wealthiest households receive these benefits, which accounts for the high meeting frequency and attendance recorded for the two types of *Samurdhi* group (Figure 4.11 and Figure 4.12).

In addition to the main village *Samurdhi* group (VDS), *Samurdhi Niyamakes* also coordinate a second tier of self-help welfare groups (SAG). These are mostly based around rotational savings / micro-credit activities (ROSCAs - locally known as *seettus*) as well as smaller '*Shramadana*' events. A minimum of six persons is required to form such a group. A single *Samurdhi Niyamake* may be responsible for between 1-3 villages, depending on their size.

Figure 4.12 also shows how most *Samurdhi* benefit (section 4.3.8) is controlled by male household heads who register for formal membership. However, although both males and females participate in *Shramadana* events, females account for most of the attendance at VDS and SAG meetings (Figure 4.12). Poorer households record marginally higher attendance levels at VDS meetings, and considerably higher involvement in SAG activities.

Although these institutions serve an important role, they operate under externally imposed formal bureaucratic rules. Consequently, relatively little scope exists for autonomous decision-making and by coupling welfare so closely with self-help, they also re-enforce a wider dependency culture.

Indigenous welfare: death donation societies

The welfare arrangements described above are in sharp contrast to the traditional indigenous village institutions known as death donation societies (DDS). Through small periodic subscriptions, these institutions subsidize the costly funereal arrangements associated with extended ritual observance. They also give small discretionary loans or grants to assist distressed households. Membership rules are rigorously enforced, with fines and threat of disbarment for those who regularly miss, interrupt meetings or fail to pay subscriptions in a timely manner without good reason. Most meetings are convened in the evening or on monthly religious *poya* days to encourage attendance.

In each village, DDS meetings were held on a monthly basis making it the second most regular forum after the VDS though equally well attended. Attendance by all wealth groups was high though again, marginally lower for poorer households. In most villages, both male and female household members were well represented amongst the ordinary membership (Figure 4.12). Whereas control of the VDS is largely a result of political patronage, the DDS executive is re-elected by its membership on an annual basis. Inevitably, influential better-off households are still over-represented. Of the seven persons holding executive positions within the sample of 41 households, four came from better-off households, two from 'medium' households and only one from a poor household in GBW.

All but one poor household in MAD held membership in at least one DDS. Unlike the other state welfare societies, DDS also attract regular external participation and subscription. The more transparent and efficient societies included a small membership from neighbouring communities. This was true of MAD despite its low-caste status. Conversely, low-caste individuals were less likely to participate in the societies of high-caste villages. Only GBW included no external members due to its remote location and small community size (25 households). Only GUR had two DDS (section 4.3.3).

Farmer organizations

Each village had a single farmer organization (FO). Despite their democratic credentials the net result of the external imposition of these contemporary organisations has been a reduction in the local sense of ownership (section 4.1.5). This is reflected in their general inactivity in the current survey (Figure 4.11 and Figure 4.12).

Formally the *vel vidane* was responsible for executing the rules and regulations pertaining to the maintenance and operation of the village tank resource. He co-coordinated a diverse range of activities; collective and individual, productive and non-productive, and participated in resolving the disputes that inevitably arose between different users. By contrast, the functions of contemporary FO are narrowly restricted to coordinating agricultural calendars and water distribution. Meetings are mainly restricted to formal planning (*kanda*) events held prior to each cultivation season, the precise timing of which is determined by the collection of sufficient rainfall in the main village tank(s). Secondary meetings may be convened to coordinate harvest arrangements, though in the current survey informal reciprocal capital and labour sharing was usually arranged directly between extended family groups or neighbours. Planning also becomes increasingly informal under smaller tanks, as fewer landholders are involved in decision-making.

FO inclusiveness is largely determined by access arrangements to irrigated lands. Consequently, they included a higher proportion of 'better-off' males, while females were excluded from any formal participation. This is despite their contribution to agricultural labour, e.g. leveling, transplanting, weeding and harvesting.

As noted above, seasonal FO activity is contingent on climatic conditions. A reversal of the usual monsoonal rainfall patterns in 2000/01 (Chapter 2), brought very different responses from the four communities. In the three upper-watershed villages: LHG MAD and GBW, the most intensive period of cultivation was delayed until the *yala* season (Apr – Jul). Only farmers in MAD also irrigated crops during the *maha* season, growing vegetables with lower water requirements, in a restricted part of the command area under the *bethma* system. More resource rich villagers in GUR responded to the erratic rainfall by cultivating lands with assured irrigation under the nearby Rajangane Reservoir.

These cropping patterns meant that while the FO in LHG and GBW each convened only one *kanda* meeting, villagers in MAD held five over the course of the year. The limited cultivation which took place under GUR was informally coordinated by the FO president and individual farmers, therefore, no *kanda* meetings were considered necessary. Dry-land cultivation took place on an individual household basis, with no FO involvement in any of the villages.

Because of the persistence of uxorilocal marriages (section 4.1.9.2) access to lands under village tanks, and therefore FO membership, continues to be restricted mainly within the *purana* complex. As noted earlier, in larger PCs ownership of lands under smaller radial tanks also tends be concentrated in the hands of households under longer settled axial base-tanks.

Other community-based institutions

Of the remaining institutions, the Temple Society was most active in GUR, the only village large enough to support its own temple and resident monk. Villagers here met once per month to plan events, assist with maintenance and took turns to provide food and alms to the priest; the *Shramadana* system still operates in the traditional manner in this instance. The other communities provided support to neighbouring temples on a less regular basis.

Other specialist institutions convened irregular periodic meetings that attracted modest attendance. These included; school development societies, women's nutrition societies (established by the health department). Political organizations had an all-male attendance and met only during local elections.

Some 37% of households in the survey also participated in informal *seettus* (section 4.3.10). Men and women participated in roughly equal numbers, though nearly 95% of participants came from medium and better-off households and nearly half the participants were in GUR. Only 12.5% of the total number of *seettus* had mixed male and female membership. Women were also much more likely to be involved in multiple *seettus*. Nearly 83% of the total number were arranged between trusted relatives and neighbours within the same village. Only in MAD and GBW were a small number of all-male *seettus* arranged with external associates.

'Youth sports societies' had been established in both GUR and MAD, but no membership / attendance was detected in the monitoring survey. These groups are also supported by the government department responsible for welfare, and as such promote both sporting and self-help activities. For example, the MAD group regularly manufactured bricks as a fund-raising activity, using clay excavated from KRB and LUN tanks.

Seasonal attendance

Seasonal attendance to meetings of each of the three welfare-based institutions (VDS, SAG and DDS) was high throughout the year in all villages (Figure 4.13). The temple society was also regularly attended in GUR. Lowest overall attendance was recorded in April and May due to cultivation commitments overlapping with New Year and other religious celebrations. Meetings of all institutions in GBW were most erratic, probably due to its small size.

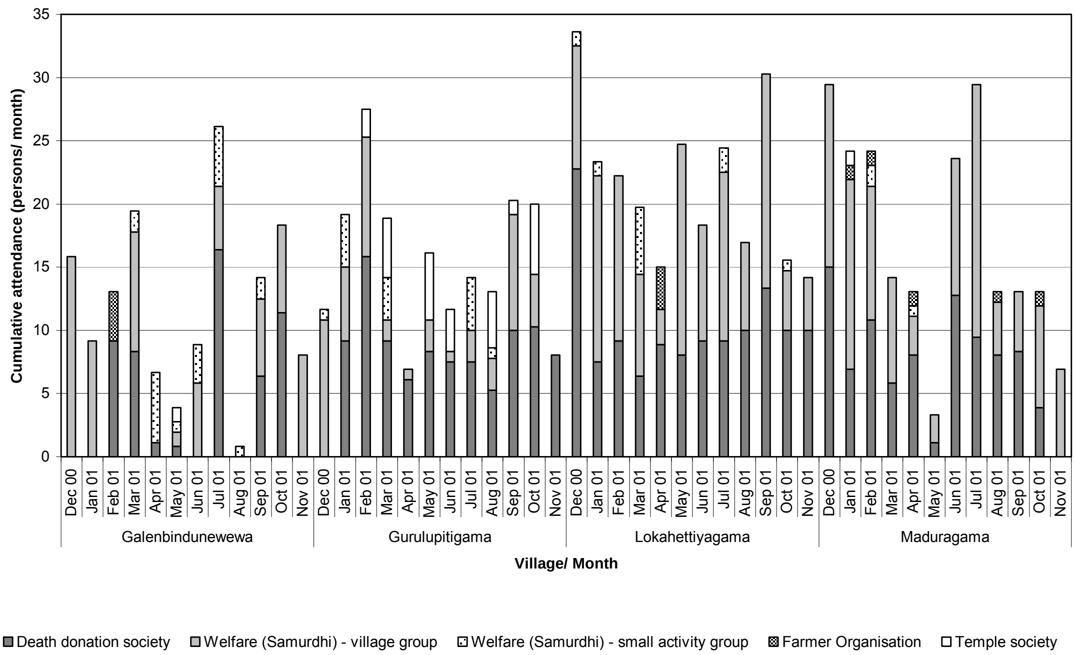


Figure 4.13 Cumulative monthly attendance at meetings of selected community-based institutions by wealth rank, gender and village location, Nov 00 - Nov 01

4.3.11 Land access and cultivation outcomes

Figure 4.14 shows the mean area of land cultivated under each of the three main production systems (section 4.2), during the *maha* 00/01 and *yala* 01 seasons in the four phase 2 intervention villages. Irrigated cultivation was further sub-divided as being under (1) complete / assured irrigation (perennial and system tanks) or (2) supplementary irrigation (seasonal tanks). Similarly, *chena* cultivation was classified as (1) 'fixed' or (2) 'shifting'. Shifting cultivation usually meant moving between adjacent plots of land, typically after 2-3 crop cycles.

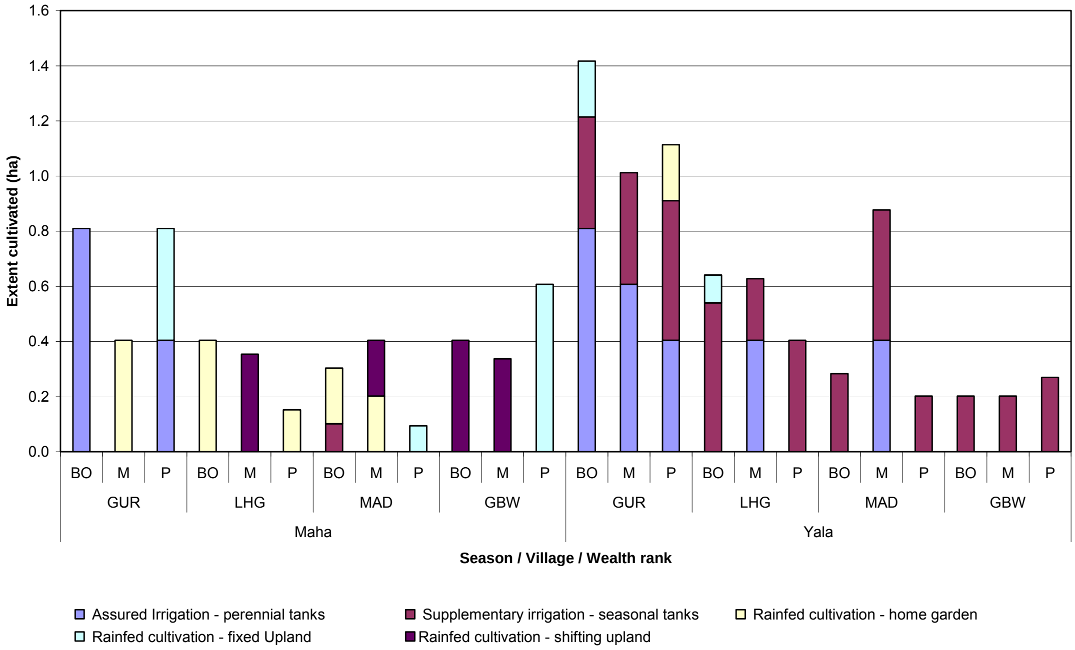


Figure 4.14 Mean area of land cultivated by season, village location, wealth rank and farming system Nov 00- Nov 01

Out of the entire sample, 11 farmers (27%) produced no irrigated crop (Table 4.3), and of this number 8 were 'poor', i.e. approximately half of all the 'poor' farmers in the survey had no direct stake in the primary use of their village tanks. For many of these farmers, fishing represented a much more important economic function (Chapter 6). Only 19 farmers (46%) cultivated rainfed crops; either as upland *chenas* or in their home-garden. This number included most of the poor farmers in the two poorest villages MAD and GBW, while only four farmers came from the two wealthiest villages, GUR and LHG.

Table 4.3 Cultivation outcomes for irrigated and 'rainfed' crops averaged over *maha* and *yala* seasons in four low-caste villages, Nov 00 – Nov 01 (based on a sample of 41 households)

Outcome / Village	GUR	LHG	MAD	GBW	Mean/ Total
Irrigated cultivation					
Mean paddy yield kg ha^{-1}	5491	5680	5141	3874	5047
Standard deviation of mean paddy yield kg ha^{-1}	1117	1107	1021	135	-
% sold or used to repay input credit	64	24	27	5	-
% retained for household consumption	34	73	72	95	-
% gifted to extended family	2	3	1	0	-
No farmers irrigating annual crops	6	7	6	6	30
Rainfed / dry-land cultivation					
No farmers cultivating rainfed annual crops	5	3	5	6	19
No. *chena* / home-garden annual crop varieties	8	11	10	4	22
% sold or used to repay input credit	77	36	42	94	-
% retained for household consumption	23	56	48	6	-
% gifted to extended family	0	8	10	0	-

Rainfed cultivation of annual crops in *chenas* and home-gardens was almost entirely restricted to the *maha* season (Figure 4.14), i.e. when rainfall is spread over the greatest number of days. Conversely, as village tanks did not fill until April, irrigated cultivation was almost entirely restricted to the *yala* season (Chapter 2). Only in two villages did some farmers cultivate two irrigated crops; in GUR three respondents owned land under Rajangane Reservoir, while one respondent in MAD was a part of small group cultivating cucumber during maha under KBW, the smallest tank in the village (Appendix 16). This was feasible for three reasons: (1) the relatively low water requirement of the crop compared to paddy, (2) low cropping intensity, i.e. only one quarter of the command area was cultivated and (3) most significantly, production was contracted to an agribusiness company, who provided all inputs and a guaranteed market at a fixed price for the highly perishable produce.

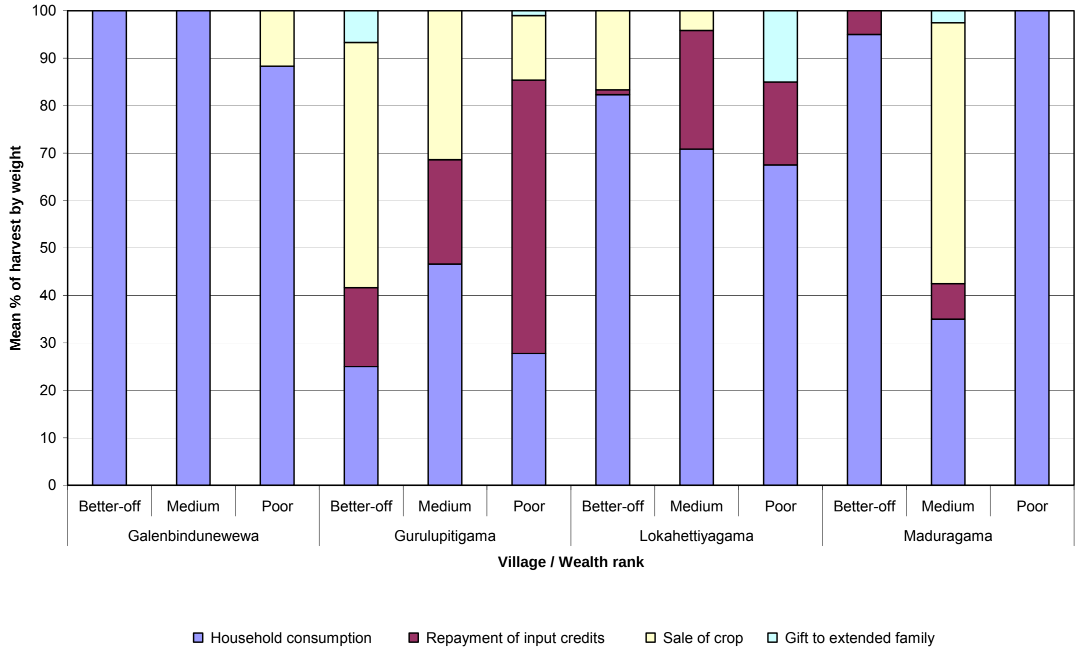
Four additional farmers, three in GUR and one in LHG, leased or share cropped external lands under external perennial tanks during *yala*, while one middle wealth ranked farmer from MAD, a refugee from the east coast town of Trincomalee (section 4.3.3), returned to cultivate his land; also under a major irrigation system. Only in GBW did farmers rely entirely on their local tanks to cultivate a single *yala* crop.

These observations account for the wide disparity in mean paddy yields between villages (Table 4.3). At 3874 kg ha^{-1} (S.D. 135 kg ha^{-1}) GBW produced only three quarters of the next highest mean yield, recorded in MAD; LHG and GUR which had the highest contribution from perennial tanks produced the highest yields. Consequently, GBW farmers (and *in-situ* MAD farmers) had negligible surplus to sell or gift to their extended families (Table 4.3, Figure 4.15.A). In other words they were compelled to be much more subsistence orientated; retaining on average 95% of production for their own consumption. This also meant that they relied to a greater extent than any other village on lower yielding *chena* cash-crops for income (Figure 4.15.B).

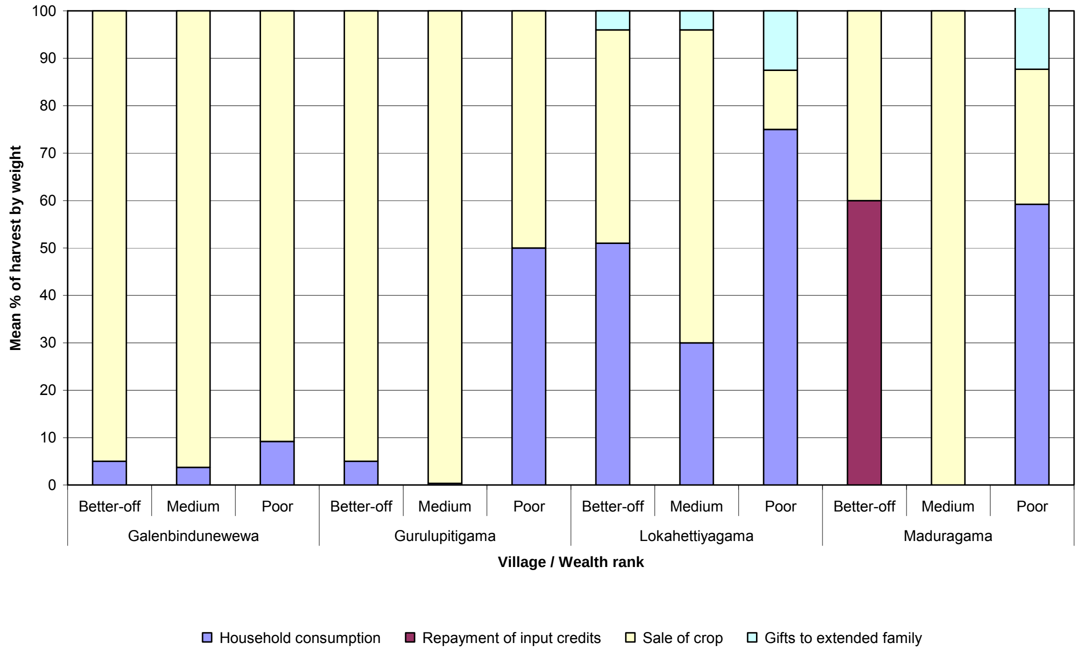
A total of 22 different annual rainfed crops were cultivated in *chenas* and home-gardens (Table 4.3); overall the greatest land area was given over to cowpea, mung, okra, long beans, brinjal and sesame. Due to the risk of elephant damage, the range was most restricted in GBW where only four relatively resistant crops; sesame, mustard, tibbatu (*Solanum indium*) and chili were grown. All households grew some perennial crops in their home-gardens, e.g. coconut, mango, banana, wood-apple etc. Collective paddy-lands are more readily protected through the organisation of rotating watches when the crop is nearing harvest.

Whereas most fixed *chenas* were privately owned, higher yielding shifting *chenas*, in LHG, MAD and GBW, were all illegally encroached on Government lands. In GBW, both shifting and a smaller number of fixed *chenas* were encroached, reflecting the recent settlement of the village (Figure 4.14). Locations of *chenas*, home-gardens and paddy lands are shown for each of the intervention villages in the social maps presented in Appendix 28.

Together, these results underscore earlier findings that relative poverty and subsistence orientation was greatest amongst the lowest caste / upper-watershed communities.



A



B

Figure 4.15 A and B: Fate of (A) paddy (B) *chena* crops harvested during *maha* and *yala* seasons in four low-caste villages, Nov 00 – Nov 01

4.3.12 Irrigation management

This research component implemented in five phase 2 intervention tanks (Chapter 3) had two main purposes: (1) to see how the different communities cooperated to manage and conserve scarce water resources (2) to assess the impacts of stocking enhancements on irrigation practice. Results are summarised in Appendix 16, Appendix 21 and Appendix 22. Due to the seasonal rainfall inversion described in Chapter 2, only one tank, KRB, reached FSL and 'spilled' during the maha season (Nov-Dec) while all five spilled during the *yala* season (April - March). KRB spilled only because of its unusual size inversion within the MAD cascade (Chapter 2), while the remaining tanks reached only 69% - 84% of capacity during the drier *maha* season. Despite these trends, farmers still cultivated substantially smaller areas; between 44% - 70% of the entire command area in KBW, SER and LHG during *yala* than they did in *maha*. This was a reasonable response to perceived risk on the part of farmers given that most seasonal tanks, even at full capacity, provide sufficient water only for supplementary irrigation of the entire command and direct rainfall tends be less evenly distributed during the *yala* season. Consequently, between 87% (SER) to 100% (all other tanks) of the command areas were cultivated during *maha* despite lower storage levels. The rainfall records in Chapter 2 show that this decision was ultimately justified.

The seasonal water storage profiles presented in Appendix 21 also indicate extremely high evaporative and percolation losses early in the season. This suggests that farmers should 'use or lose' water at this time. The problem is likely to be most pronounced in upper-watershed areas where permeable red soils predominate. Conservation practices are only likely to be fruitful when containment is confined to the deeper dead storage area, with its better-developed silt layer and hard pan, i.e. during the dry season. Once again such findings correspond with observed practice. For example, some farmer organisations promoted the use of rainfall rather than stored water for paddy preparation, but only when commencing cultivation with sub-optimal storage. In MAD, better-organised farmers also increased synchronisation of their irrigation releases as water levels fell while releases were most erratic in LHG. Farmers in MAD also reported that the presence of stocked fish also prompted them to be more conservative in their end of season irrigation practices (Chapter 6).

4.3.13 Livestock

The numbers of large ruminants in most villages appeared to be declining against a background of already low holdings (section 4.2.3). Farmers attributed the decline to three main factors; firstly, they felt that decreasing pasture availability had increased the risk of financial penalties associated with livestock incursions and crop damage. However, colonial records suggest that this was a highly significant problem in this area even during the nineteenth century (Wickremeratne 1985). Greater weight can therefore be attributed to the second cause; an unwillingness to invest greater effort in shepherding herds in *lieu* of other more profitable off-farm labour opportunities, i.e. this would involve a movement away from the low input husbandry systems still practiced by most small-holders. Thirdly, and perhaps most significantly, there is a lower requirement for draft power as a result of increasing farm mechanisation. Water-buffalo numbers appear to have declined more rapidly as they are replaced by tractors for paddy preparation. In addition, their grazing habits make them more difficult to manage than cattle (Murray 2004b).

Attempts to promote commercial milk production have met with little success due to a range of cultural, marketing and technical factors. The low-yielding but hardy *sahival* cattle variety still predominates. Consequently, small-holders still view cattle and buffalo as savings assets with a secondary draft function.

Goat holdings appear to have increased; in part due to the promotion of small enterprise initiatives by development organisations targeting women's groups, their husbandry being highly compatible with prevailing gender labour division. For example goats can forage on a wide range of foodstuffs in close proximity to the household, while men are more likely to collect fodder for cattle and buffalo where this involves travelling longer distances. Whereas women and children are often solely responsible for goat herds, both male and female household members shepherd cattle and buffalo. Men are also responsible for most financial transactions involving livestock.

As little of this livestock is consumed locally, off-sales mostly took place outside the villages. These were mainly mediated by middlemen from a small number of Muslim communities scattered around the project area. These relations have also given rise to a share-holding system whereby households attempt to establish their own herds, by retaining half of any off-spring from animals that they shepherd for third party owners, both external and local.

Livestock holdings in the five phase 2 intervention villages were assessed using key informant interviews triangulated against household monitoring data (Figure 4.16). Only information for the three principle ruminant livestock varieties noted above are presented although many households also kept chickens for their own consumption. Only one household in LHG kept pigs as a business enterprise.

Cattle and goats were most abundant though cattle were the only livestock variety present in all villages. Buffalo were present in three villages, though only farmers in MAD, who still relied on draft-power for ploughing, retained substantial holdings. Ownership frequencies were highest in SER and GBW, where respectively, 71% and 56% of households held at least one of the three ruminant varieties. These values fell to 16% and 17% in MAD and LHG respectively and only 8% in GUR. Total holdings followed a similar pattern with a mean of 3 cattle and 5.8 goats per household in SER, and 3.8 head of cattle per household in GBW. Mean holdings for other villages and varieties were all below 1.4 animals per household.

The main reasons for these trends are as follows; firstly, local pasture resources were greater around the first two villages, especially SER with its access to IMKs many village tanks. Secondly, villagers in GBW had received sizeable grants to purchase cattle under the previous regimes *Janasaviya* welfare system (section 4.3.8). Thirdly, villagers in LHG and GUR had greater off-farm livelihood opportunities and finally in GUR, the most accessible village by road, organised thefts were a recurrent problem.

Only 9% of livestock owners held them on a ‘share’ basis. These were exclusively ‘poor’ wealth ranked households while goats were the predominant livestock variety held under these terms. This was because of their relatively high fecundity, ease of management and their lower individual value and hence risk of incurring financial losses due to disease, theft etc.

While 40% of livestock owners were poor, no ‘poor’ household owned more than 7 cattle or water buffalo. Larger herds of 18 to 40 head were owned almost entirely by better-off households. By contrast, only one better-off household in SER owned goats while poor households were just also likely to own large herds of up to as many as 30 to 60 animals.

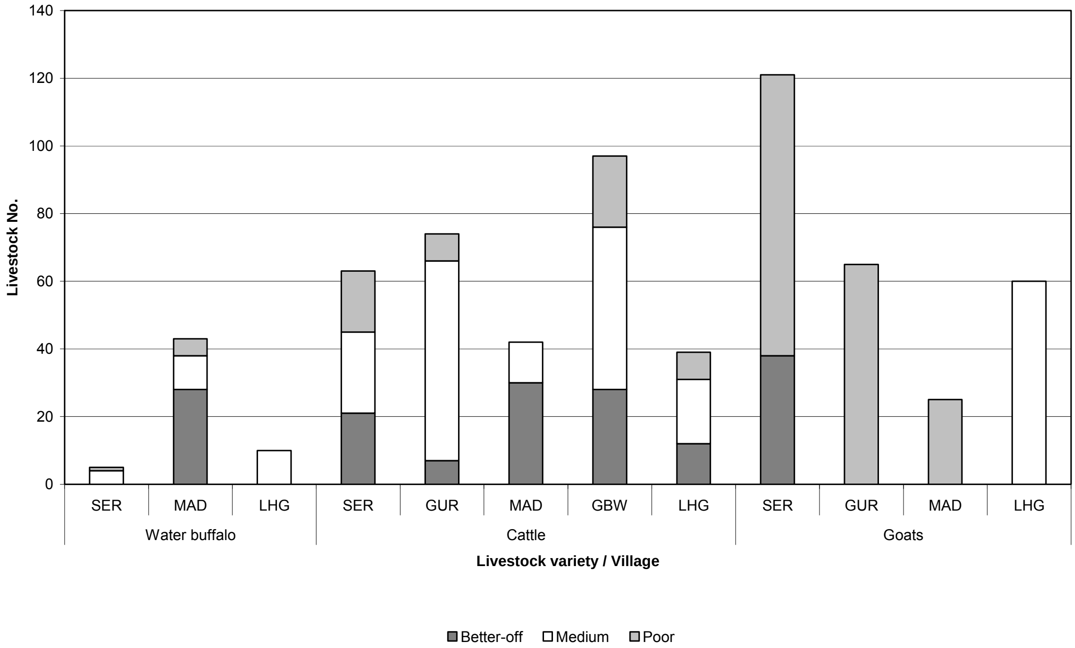


Figure 4.16 Total livestock holdings by wealth rank in five Giribawa intervention villages

4.3.14 Needs Analysis

Needs analyses were carried out during the introductory PRA phase (Chapter 3), in order to understand farmers' livelihood priorities and how aquaculture interventions might fit into these. Results also contributed to the action-research site selection process. Analyses were undertaken in three of the low-caste communities in upper-watershed locations, and four high-caste villages in mid to upper-watershed locations (Table 4.4). PCs ranged in size from 39 to 106 households, with access to between 2 and 19 village tanks. Four of the villages: ULP, IMK, LHG and MAD, subsequently became intervention sites.

Responses to the dummy question; 'how have things improved over the last 10 years?' elicited lists of infrastructural benefits provided by State and NGO agencies. These included provision of drinking water wells, road improvements and tank rehabilitation measures (improvements to head-works and partial de-silting).

A total of seventeen inter-related criteria were identified in response to the second question: 'how have things got worse over the last 10 years?' These encompassed the entire range of livelihood assets. Criteria are presented in order of importance, based on their overall citation frequency and median ranking outcomes in each village (Table 4.4). Friedman's analysis indicated a high degree of intra-community consensus ($P < 0.01$).

The top ten criteria were cited in at least five of the seven villages. However only 'lack of water for cultivation' was cited in all seven instances, being ranked among the top 3 criteria except in MDW, where it was ranked fifth. This was the highest caste and probably most affluent village in the GBW area, where most farmers had acquired land with assured irrigation under Rajangane Reservoir (section 4.3.2). 'Lack of regular income sources' was cited on six occasions; ranked first, four times and second, twice. Many farmers reported increasing reliance on off-farm income sources as pressure on local land and water resources had increased. Again only in MDW was this criteria not cited at all.

'Food insecurity' and 'poor education facilities were both cited in six villages (once again except in MDW) and consistently ranked amongst the top six criteria. Many participants reported that they were compelled to reduce the quantity and quality of food stuffs during lean periods in the agricultural calendar as a coping strategy. The high ranking of 'poor education facilities' was surprising set against national statistics, but consistent with the local literacy assessments presented in section 4.3.7. However, the result also reflects the increased expectation and value placed on education, coupled with a perception that there has been a recent decline in standards.

Four other criteria were cited on at least four occasions. Uppermost of these in terms of ranking outcomes was the threat posed to crop production by wild animals (section 4.3.11). Two other criteria in this group related to poor service provision; health care and transport. Although all the villages were accessible by un-surfaced tracks, only those located more than 1km from a bus route cited transport as a problem. 'Health care' results followed a similar trend suggesting that the problem was related to access as well as the quality of health services. The fourth criteria related to the low prices many farmers receive for their agricultural produce, is associated with poor transport and market infrastructure in the area. Most farmers are price-takers, particularly when they engage in production of more perishable 'other field crops' (OFCs; i.e. non-staples). Terms of trade are frequently dictated by suppliers of agricultural inputs under fixed-credit agreements, or by bulk traders who visit villages during harvest periods. This is in marked contrasted to the highly accessible and equitable markets for inland fish (Murray 2004a).

The remaining nine criteria were each cited on between two to four occasions. They include deficits in service provision: electricity, communal drinking water facilities, along with poor access to agricultural extension and vocational training opportunities. Two other criteria related to the over-exploitation of the natural-resource base. The first; 'decreasing soil fertility' was attributed to the intensification of irrigated agriculture following the introduction of high yielding varieties and increasing farm mechanisation over the last two decades. Villagers in Giribawa had greater reliance on the harvesting of timber and non-forest timber products (NFTP), and frequently cited the unsustainable exploitation of these resources as an important constraint. Longer settlement and clearance of primary forest areas in Anamaduwa has also eliminated the elephant threat described above.

Poor housing achieved an intermediate position presumably because many households had by now achieved their goal of building permanent homes. Problems relating to social asset formation were more difficult to assess. Firstly, this requires an unambiguous definition of what exactly constitutes social assets and secondly, how the extent of such assets can be measured in any tangible way. Thirdly introductory group meetings such as this are not the best forum to solicit such information. In other PRA exercises, individual key informants expressed the view that there had been significant decreases in social cohesion, particularly over the previous two decades. This was attributed to increasing population, greater reliance on off-farm labour including long term female remittance labour, politicisation of public service provision and alcoholism. Only the last of these impacts was explicitly identified in the needs analyses, and only this criteria was consistently scored this higher by women than men (Table 4.5).

Table 4.4 Median ranks of scores and Friedman's analysis of basic needs assessed in six *purana* villages in Giribawa and Anamaduwa Districts (1 = most important rank)

Needs Criteria / **Friedman test results** / community characteristics	**Village[1]**							**Cum. Freq.**
	ULP[2]	**DAN**	**MAD**	**LHG**	**PMK**	**IMK**	**MDG**	
1. Lack of water for cultivation	2.2	3.6	2.8	4.3	2.4	2.9	5.0	7
2. Irregular income / few job opportunities	2.8	3.6	2.6	3.8	2.7	2.6		6
3. Food insecurity	3.0	6.6	5.9	4.8	7.6	7.6		6
4. Poor educational facilities	5.3	5.3	7.7	6.8	6.2	4.5		6
5. Wild animal threats to crops		4.7	4.5	5.7		3.1	1.0	5
6. Low prices for agricultural produce	5.3			5.8	5.3	8.1	2.0	5
10. Poor access to health care	6.3			6.8	5.2	7.9	4.0	5
8. Poor roads / lack of transport facilities	4.6		5.3		8.1	7.4	6.0	5
7. Insufficient drinking water facilities		9.7		6.1	6.1	7.3		4
11. Alcoholism		4.0	7.8	10.8			7.0	4
14. No electricity supply		3.8			8.1		3.0	3
9. Poor housing			6.5	10.8		3.6		3
17. Loss of forest resources			7.1	9.9			8.0	3
13. Rising cost of agricultural inputs	6.4			3.9				2
12. Few vocational training opportunities			4.8		6.8			2
15. Poor access to agricultural extension		8.3			7.7			2
16. Declining soil fertility		5.4		11.4				2
N (participants)	**10**	**14**	**14**	**29**	**18**	**8**	**7**	
N (Female participants)	**3**	**6.0**	**9**	**5.0**	**7**	**0**	**0**	
N (groups)	**10**	**9**	**13**	**8**	**18**	**7**	**1**	
$\chi 2$ (Friedman)		**48.5**	**47.7**	**53.3**	**67.2**	**39.8**	**NA**	
Degrees Freedom (DF)		**9.0**	**9**	**12**	**10**	**9**	**NA**	
Probability (P)		**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**NA**	
Venue[3]	Con	Con	DDS	Con	DDS	VW	Con	
Watershed location[4]	U	U	U	U	M	M	M	
Caste[5]	P	F	G	BS	F	F	F	
No households	10	32	51	47	39	107	56	
No tanks	2	3	3	2	2	19	7	
Cumulative tank area (ha)	2.83	7.49	17.2	15.6	16.58	55.1	41.4	
Tank area (ha) : household	0.28	0.23	0.34	0.33	0.43	0.51	0.74	

[1] ULP = Ulpathwewa, DAN = Danduwellawe, MAD = Maduragama, LHG = Lokahettiyagama, PMK = Pahala Maradankadawala, IMK = Ihala Maradankadawala, MDG = Madawalagama
[2] ULP located in Anamaduwa District, all other villages in Giribawa District.
[3] Con = convened meeting, DDS = death donation society, VW = village welfare society
[4] U = upper watershed, M = mid watershed
[5] P = potter, F = farmer, G = gypsy, BS = blacksmith

Table 4.5 Median ranks of scores and Friedman's analysis of basic needs assessed in four *purana* villages of Giribawa district by gender (1 = most important rank)

Needs Criteria / **Friedman test results**	**Village / Gender**							
	DAN		**LHG**		**MAD**		**PMK**	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**
1. Lack of water for cultivation	3.6	3.5	4.7	3.3	2.4	3.5	2.4	2.6
2. Irregular income / few job opportunities	3.6	3.5	4.0	3.3	2.8	2.1	2.3	3.4
3. Food insecurity	6.2	8.0	3.8	7.8	6.1	5.5	7.6	7.5
4. Poor educational facilities	5.9	3.5	7.1	6.0	7.2	8.8	5.6	7.1
5. Wild animal threats to crops	4.6	5.0	6.5	3.3	5.6	2.1		
6. Low prices for agricultural produce			5.3	7.3			5.0	5.6
7. Insufficient drinking water facilities	9.6	10.0	4.7	10.5			7.5	3.9
8. Poor roads / lack of transport facilities					4.7	6.6	9.0	6.6
9. Poor housing			11.0	10.3	6.8	5.8		
10. Poor access to health care			7.1	6.0			5.0	5.6
11. Alcoholism	3.6	5.5	12.3	6.0	7.4	8.6		
12. Few vocational training opportunities					5.3	3.6	7.1	6.1
13. Rising cost of agricultural inputs			3.8	4.5				
14. No electricity supply	3.9	3.5	14.0	14.0			7.5	8.9
15. Poor access to agricultural extension	8.1	9.0	14.0	14.0			7.1	8.7
16. Declining soil fertility	5.9	3.5	11.1	12.5				
17. Loss of forest resources			9.7	10.5	6.5	8.4		
No participants	**8.0**	**6.0**	**24**	**5**	**9**	**5**	**11**	**7**
N (groups)	**7**	**2**	**6**	**2**	**9**	**4**	**11**	**7**
x2 (Friedman)	**36.2**	**16.7**	**47.5**	**18.2**	**28.6**	**28.6**	**50.4**	**28.7**
DF	**9**	**9**	**12**	**12**	**9**	**9**	**10**	**10**
P	**<0.01**	**0.05**	**<0.01**	**0.11**	**<0.01**	**<0.01**	**<0.01**	**<0.01**

Notes: M = Male, F = Female

4.3.15 Coping strategies

The preliminary needs analysis was complemented by an assessment of coping strategies in the phase 2 household baseline survey (Chapter 3). The 41 wealth stratified households in GUR, LHG, MAD and GBW were asked to cite and rank the main strategies they employed during the drought year spanning 1999/2000, prior to interview. Only citation frequencies are presented here.

Thirteen different strategies were identified (Figure 4.17) of which: five related to different kinds of food or meal adjustments, three related to formal and informal types of credit, three involved short or longer term migration of household members including placement of dependents, two related to sale of agricultural produce, and one; ‘food aid’, to welfare benefits. Poorer households resorted to the greatest number and variety of coping strategies.

Only informal credit, available through boutiques, friends and family or village money lenders, was cited in every instance. Pawning of jewellery and other household assets was cited by all but better-off households in GUR. By contrast, formal credit from rural banks, mainly for cultivation inputs and house construction, was only available to better-off and some medium wealth rank farmers. Remittances, a large proportion from women in the garment sector, were important to all wealth groups. Shorter term labour migration was only cited by poorer households from MAD; internal displaces from Trincomalee who return to cultivate their fields. Much of the other ‘off-farm’ agricultural and coolie work undertaken by other farmers is day labour.

Emergency sales of crops were cited by all but the poorest households in GBW. These consisted of items with good storage qualities; irrigated paddy and highland pulses; mung and cowpea. Livestock sales were cited only by two of the poorest households in MAD and LHG.

‘Food aid’ included food for work schemes, which took place in LHG and MAD, and the *Samurdhi* food stamp. Consequently, it was cited by nearly every group. By contrast, food adjustment strategies: food substitution (e.g. manioc, maize, cowpea and wheat for rice and fish for vegetables), meal sharing, frequency and quantity reduction, and ultimately redistribution of dependents, were practiced mainly by the poor along with smaller numbers of medium wealth households; especially in MAD and GBW. Further details of food and meal adjustments were collected in the longitudinal survey and are discussed in Chapter 6.

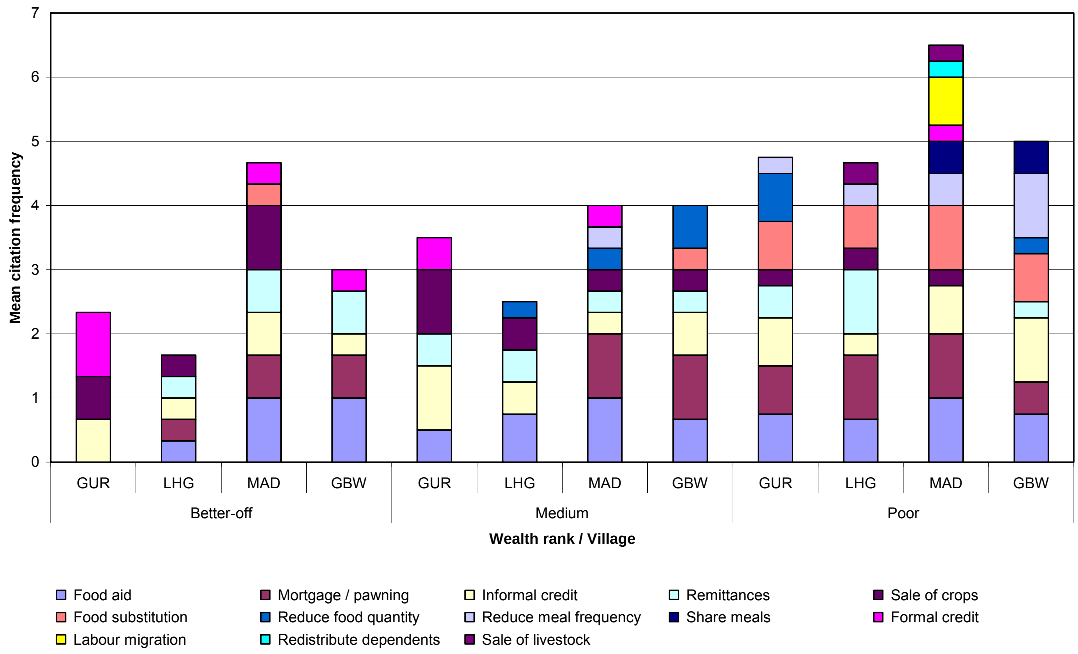


Figure 4.17 Mean citation frequency for household coping strategies by wealth rank in four intervention villages in the Giribawa area (1 = cited by all households)

4.3.16 Conclusions

Many of the livelihood characteristics described above are consistent with a general movement from subsistence to cash economy following liberalisation. Most notable was an increased reliance on off-farm employment while increased dependency on external institutions is also a legacy of the centrally planned era. Many traditional collective management activities, particularly those relating to water (de-silting, collective-fishing, *bethma* etc) also appear to be being progressively abandoned, or in some cases, already on the edge of memory.

Despite this re-orientation, the basic food-security of poorer groups still ranked as a fundamental problem which might be alleviated by increased aquatic production. This emerged more clearly from the assessment of coping strategies than the 'needs analysis', which tended to under-represent poorer households, and inevitably tended to focus on infra-structural and service delivery. Poorer lower-caste groups in upper-watershed areas also remain relatively more dependent on subsistence production strategies for their livelihoods. In these areas, aquaculture is consistent with the buffer-zone concept, i.e. increased aquatic production could reduce dependency on forest resources, risks associated with crop damage and therefore human-elephant conflicts.

How to identify the best entry points to work in partnership with communities on the sustainable and equitable management of common property resources was one of the questions addressed in the institutional analysis. Development organisations routinely target FOs for rural development interventions, particularly those incorporating water management components. However, this analysis indicates that these institutions are only periodically active and exclude women, along with many poorer households without access to irrigated lands. Furthermore, they are likely to be least active during periods of chronic water shortage, when trade-offs between alternative uses become more critical. By contrast, the indigenous DDS were far more inclusive, regularly active and probably the most efficient and well-respected institutions in every one of the communities investigated. Furthermore, they also appeared to offer a potential route for cross community collective activity.

Preliminary attempts to convene meetings, specifically to discuss issues relating to stocking, met with highly inconsistent responses. DDS meetings were therefore identified as the most suitable forum to interact with the broadest cross-section of the communities in the action-research phase. The outcomes of such meetings, which took 30-40 minutes to prior to, or after the DDS agenda, are discussed in Chapter 5.

The analysis also showed clear differences between the villages arising from social attributes such as caste and kinship and inter-related patterns of resources access.
Based on a variety of indicators, GBW emerged as the poorest and GUR the most affluent community, with LHG and MAD in intermediate positions (though social stratification in LHG was clearly much greater). Overall differences between wealth and gender groups were least marked in MAD; socially, the most cohesive village. Based on attendance recorded at eight internal societies, MAD also recorded the highest institutional diversity.

Chapter 5 Community-managed trials based on stocking enhancement in seasonal tanks

5.1 Introduction

In this chapter, the outcomes of two phases of action research based on community-managed stocking interventions are assessed. Low-input enhancement strategies based on self-recruiting tilapias and other locally available indigenous species are described. Their selection was based on the following factors (1) a critical assessment of state sponsored culture-based carp stocking programmes described in Chapter 1 (2) a review of traditional subsistence-based systems of fisheries management in seasonal tanks and contemporary practices in our research areas in the first section of this chapter. This included a baseline survey of collective-fishing practices in each of the *purana* complexes (PC) identified in Chapter 4 (3) an assessment of secondary and primary stakeholder analyses staged to formulate a participatory research agenda.

Phase 1 trials were based on the use of hatchery-produced *O. niloticus*, in a range of physical and social settings; tanks of variable size, seasonality and associated community characteristics. The results led to a shift in focus in the second phase, to the smallest seasonal tanks belonging to marginal low-caste communities in upper-watershed areas. These trials relied on stocking a range of wild-sourced seed including tilapia and snakehead.

In addition to a reliable source of fish seed, effective community based institutions (CBI) capable of planning and implementing management systems are a requisite for mutually beneficial collective action in these CPR's. In both phases, the strategies adopted by the different communities are also described and evaluated.

A wide range of different monitoring methods were simultaneously applied in order to capture the multi-dimensional complexity of competing stakeholder interactions and the spatial and temporal dimensions of resource extraction (Chapter 3). In this chapter, results of the direct observational and key informant techniques are reported. These included; monitoring of collective fishing activity, researcher-managed test fishing. The results of two concurrent social-survey techniques operated during the phase 2 trials are reported in Chapter 6. In line with project goals, priority in both chapters is given to assessing how equitably benefits were distributed amongst different wealth groups, and potentials for sustainable adoption.

Section 1. Management Options

5.2 Traditional and contemporary management of subsistence fisheries in seasonal tanks

Traditionally, seasonal tank fisheries in the Dry-Zone were managed to exploit naturally-recruiting stocks on a subsistence basis, in a highly extensive, though sustainable manner. Historical evidence suggests that at one time, male members of almost all families in a village would be involved in occasional fishing to supplement their diet (Siriweera 1986). Rarely were fish caught for commercial purposes.

Under the smallest, often private irrigation tanks, only owners had fishing rights. Where tanks were common property resources, only villagers within the village had the right to utilise the fisheries within them came under the management of formal village institutions. Regulatory activities were coordinated by the hereditary village irrigation leader (*vel vidane*). When the water level dropped during the rice-growing period, the *vel vidane* imposed a prohibition on fishing to prevent conflicts with other users for the priority functions of irrigation, bathing, and livestock watering and possibly human consumption (Chapter 2). Finally, on a date set by the headman, all able-bodied males were expected to participate in collective fishing using their own equipment over a prescribed number of days.

As well as minimising disruption for other uses, this collective practice facilitated distribution of catches according to well established normative rights (i.e. not enshrined in any formal legislative framework). This ensured that needier households received a share, while simultaneously re-enforcing hierarchal power structures within the community. Shares were set-aside for those incapable of participation, e.g. female headed households and the sick, as well as those who did not participate for reasons of status and belief, e.g. ‘respectable’ families and the local Buddhist temple. The share received by participating households, was often determined by the extent of its paddy lands, in the same way as the irrigation requirement for water under *bethma* (Chapter 4).

The practice of collective fishing also had the benefit of reducing fish populations before over-crowding caused mortalities which could pollute shrinking residual storage in smaller seasonal tanks. (Ulluwishewa 1995) reported that after any irrigation requirements had been met, very often even collective fishing would be banned in one or more of the village's larger tanks in order to conserve the remaining water supply during the dry season. This provided more permanent refuges for fish, allowing them to breed and subsequently migrate to smaller tanks, thereby conserving stocks in the whole system. Universal imposition of these restrictions also limited villager's access to external tanks, compelling them to conserve the fishery resources within the village boundary.

Although relatively inefficient, traditional fishing methods tended to be size and species selective, permitting juveniles to escape thus preventing over-exploitation of the fishery. With the exception of rod and line all the traditional fishing techniques could be practiced only in shallow water and these methods have graphically been described as 'mud-fishing' (Fernando 1963). Today, higher CPUE is associated with modern encircling gears and gill nets, though in upper-watershed areas, where erratic seasonal yields merit lower expenditure, farmers continue to use the traditional wicker hand traps (*karaka*) alongside the few nets they own or borrow (section 5.5.7).

Various cultural attitudes many of which persist also contributed to the sustainability of the system. A belief that it is wrong to catch fish struggling to survive in the mud, contributed to continuity of the fish community during the dry season (Plate 5.1). Other villagers looked down upon people breaking this taboo, or upon those practicing fishing as a primary occupation. Hook and line fishing using bait attracted greater opprobrium, as it is associated with the taking of additional life and the pollution of bathing water (Murray 2004a). Such taboos continue to be more rigidly perpetuated in higher-caste communities.

Plate 5.1 Kandyan-period temple fresco (>200 years BP) portraying the 'merit' associated with the preservation of aquatic life in a seasonal village tank; Sasseruwa Buddhist Cave Temple, North West Province (land crabs, once common in paddy fields are now rare – farmers attributed this to the intensified use of pesticides).

A second type of brief but intense fishing activity was, and remains associated with seasonal spill events. The practice has a strong recreational component, but is also a pragmatic response to high CPUE potentials which occur as large numbers of fish migrate between tanks. A variety of low-cost, improvised active and passive-fishing-gears, including sweep nets and traps, are used, while 'beating' with an iron rod and torch is practiced at night. Perhaps because of this natural bounty, and because the activity is confined to ephemeral streams where there is little scope for conflict, these practices too have become normalised and there is little or no social taboo on participation. Yields fluctuate dramatically between years depending on rainfall characteristics (Chapter 3). Mass-migrations and extremely high catches were reported in 1983/84 and 1997/98 while very few tanks spilled during the three low rainfall years prior to our action research (Chapter 2).

The ecological and social conditions that contributed to the traditional sustainable utilisation of fishery resources have altered dramatically over the last few decades. Rising population, agricultural intensification and uncoordinated tank rehabilitation, have compounded problems of water quality and scarcity within watersheds, which threaten the survival of less hardy species. Traditional village institutions, together with the value systems that sustained them have also changed during the transition to a market economy, and villagers are increasingly reliant on off-farm resources including tilapia from commercial perennial-reservoir fisheries.

Many of the practices outlined above are now moving towards the edge of memory while at the same time being increasingly romanticised along with other rural traditions, as nationalist agendas spill over into the development discourse (Chapter 4). Indeed, findings presented below will cast doubt on whether the seasonal-tank fishery was ever as strictly demarcated as the preceding accounts suggest. Today, collective fishing is still the norm, though it is increasingly opportunistic; predicated on individual or group rather than formal cooperative effort. The more extreme examples of such free-for alls might more realistically be described as 'mass fishing' reflecting this loss of collective organisation. Technical advances, namely the introduction of low-cost efficient modern gill nets has probably also contributed to this trend, i.e. smaller fishing groups can achieve threshold CPUE levels that previously required more concerted collective effort, making collective-fishing possible in the residual storage of larger tanks than in the past.

These trends have contributed to a devaluation of the subsistence fishery amongst the better-off villagers who can most afford to purchase fish and no longer benefit from the automatic status enhancement intrinsic to the traditional system. Many of these elites are more concerned to enforce fishing bans which consolidate their influence over other water uses rather than promoting fisheries enhancements which are increasingly the cause of conflicts with poorer minority groups. The same trends also create substantial inertia against more positive change. Yield gains which might result from staggered harvesting strategies based on tilapia or carp stocking, are eschewed by the same groups, in favour of traditional single harvest strategies which they can more easily regulate.

Most of the available secondary data relating to collective harvesting periods has little to stay about more regular but low intensity and less visible 'staggered' harvesting. During the phase 2 trials (section 5.6), five seasonal fishing periods were identified. These were differentiated by a variety of fishing practices; themselves a response to changing hydrological conditions, and restrictions associated with the primary water uses, e.g. cultivation and bathing. Three periods of staggered, mostly individual effort using hook and line, were interspersed around the group 'spill-fishing' and 'collective harvesting' events (Table 5.1). Most fishing, during all periods, was 'active' rather than 'passive'; one exception being the use of simple barrier gears during spill events

Plates 5.2 A and B). The main reason for this was threat of gear loss, particularly during informal / unsanctioned events. Although hook and line fishing is indicative of individual effort, here too, groups of participants would often pool their catches, particularly when fishing was geared more to recreation than subsistence.

Table 5.1 Classification of seasonal fishing practices in small village tanks stocked during 2001

	Fishing period	Type of fishing	Individual (I) or group (G) ?	Level of intensity	Main Gears[1]	Month
1	*Yala* inundation	Staggered (i)	I	Low	HL	Mar
2	Spill-fishing	Spill-fishing	I & G	Medium-high	B, HN	Apr
3	Post inundation	Staggered (ii)	I	Low	HL	May - Aug
4	Post *yala* cultivation	Collective	G	High	GN, SN, HT	Aug - Oct
5	Inter-monsoon	Staggered (iii)	I & G	Low-medium	GN, MF	Sep - Oct

1 HL = hook and line, B = 'beating' with iron rod, HN – Hand nets and other improvised barrier gears. GN = gill-netting, SN = seine netting, HT = '*karaka*' snakehead hand traps, MF = 'mud-fishing'

Further details of contemporary management practices were revealed during a systematic survey of collective fishing events in ten cascade systems, reported in the following section.

5.2.1 Baseline survey of collective fishing events

Results of the collective fishing (CF) baseline survey which took place from July to September 2000 (Chapter 3) are presented in Table 5.2. CF took place in only 25% of the total sample of tanks, inclusive of three of five stocked tanks. This low outcome was due in large part to low levels of standing fish stocks associated with a sequence of unfavourable hydrological conditions (Chapter 2). The smallest tanks were worst affected; i.e. only around 7% of the most numerous radial tanks were harvested. This proportion rose steadily with increasing tank size, to 52% and 83% of 'axial 2' and 'axial 3' tanks respectively. Thereafter, levels tailed of again as the residual storage of higher order axial tanks, which are typically perennial, seldom falls low enough to trigger collective fishing (Table 5.2).

Events lasted from 1 to 4 days with more protracted harvesting occurring in larger tanks. Negligible irrigation demand during *yala* 2000, meant that the onset dates for fishing events at low water correlated closely with tank size; with most smaller tanks being harvested up to a month or more before the largest ones (Table 5.2). Marginally higher annual rainfall levels in Anamaduwa District also appeared to result in a slight delay in the onset of harvesting compared to Giribawa (Chapter 2).

Table 5.2 Collective fishing activity in ten watersheds of Anamaduwa (AND) and Giribawa (GIR) research areas, Jun - Aug 2000

	Tank Class					**Research Area**	
	Radial	Axial 1	Axial 2	Axial 3	Axial 4	AND	GIR
No. tanks investigated	41	19	6	6	5	25	52
Without collective fishing	38	14	3	1	2	18	39
With collective fishing	3	5	3	5	3	7	13
% With collective fishing	7.3	26.3	50.0	83.3	60.0	28.0	25.0
Min MWS (ha)	2	2.02	6.07	3.125	14.58	3.125	2
Max MWS (ha)	8.1	13.56	18.1	25.9	38.5	38.5	25.9
CF start date	28-Jun	16-Jun	27-Jul	14-Jul	25-Aug	25-Jul	15-Jun
CF end date	27-Jul	12-Aug	1-Aug	20-Aug	27-Aug	27-Aug	20-Aug

Only in two non-intervention tanks were CF events formally announced by village institutions, giving villagers several days notice to prepare. In one instance, the event was organised to avoid a fish kill due to pumping of residual water storage for emergency irrigation. In the great majority of cases however, spontaneous ‘mass fishing’ episodes are triggered by a shift from chronic, low-level to intense poaching associated with falling water levels and increasing CPUE. Poaching, which mostly takes place during the night, is often initiated by locals who then invite external friends with access to fishing nets to join them. In the absence of effective regulation, the onset of such events corresponds with a threshold CPUE level, below which it is feasible to (re)impose a fishing ban that requires minimal enforcement beyond broad social consensus. For all but the very poorest households, this threshold typically appears to be around 1kg of fish constituted of individuals mostly above 50g in weight, in return for half a day’s effort.

In spite of their unregulated nature, such mass fishing events were usually tolerated, or even sanctioned by village officials, in order to mitigate longer term multiple water-use conflicts. Over 90% of communities reported that formal organisation of fishing and yield distribution as described in section 5.2, had not taken place for between 10-25 years. Today, most fishing is by small teams of male participants, who come from both within and outside the immediate community; cooperating in the procurement and deployment of fishing nets as described below. Owing to fear of theft, gill nets were rarely fished passively, i.e. by leaving them *in-situ* overnight. Although, they are widely available at relatively low cost from retail sources close to adjacent perennial fisheries, only those involved in regular fishing activity are likely to own their own nets.

The unpredictable onset of mass fishing events also influenced who was likely to participate as a result of the way in which knowledge of events was disseminated in and around the village. This had far reaching consequences for yield distribution (section 5.5.8). It also made it very difficult to plan direct observation of these events, which were usually encountered more by chance than design. In the case of all but the smallest tanks, local villagers were likely to invite friends and relations from neighbouring communities to assist in the harvest. Such invitations were typically predicated on external participants bringing additional fishing-gears but also incorporated an important recreational component; which often involved the consumption of alcohol. Gear loans might also be made without the direct participation of owners for a smaller share of the catch.

The level of external participation typically increased after the first one or two days. This was due both to the spread of knowledge of the event through gear loan and / or marketing channels, and greater tolerance of external participation by the local community as CPUE falls. This semi-open system has various advantages and disadvantages in terms of the benefits which accrue to the local community:

- Although news of the event typically spreads very rapidly through the host village, those without male representation on that particular day (i.e. due to off-farm labour commitments etc.) are often excluded. Such losses are offset to various extents by the informal distribution of surplus catches amongst kinship groups.
- Control is effectively ceded from influential village officials, often to lower status groups, with consequences for the social cohesion of the local community (section 5.5.9).
- Unregulated external participation involves the loss of fish production to the immediate community. However limited transfers of harvested fish can also be viewed as a rational and cost-effective means of 'renting' fishing nets. Greater

mutual exclusion would require increased internal ownership of gears likely to be put to sporadic and un-economic seasonal use. The loss can also be discounted against the greater fishing efficiency and CPUE that results from (1) collective clearance of net-fouling weeds (2) large numbers of participants' strategically or inadvertently driving remaining fish into each others' nets.

- 'Losses' are also offset or entirely recouped through reciprocal participation in neighbouring tanks in the same or adjacent watersheds. Collective fishing at this broader level might therefore be viewed as a more efficient and pragmatic way of managing stocks. However in terms of equitable distribution and conflict potentials, much will depend on site-specific social factors, such as the juxtaposition of different caste groups, distribution arrangements for non-participants as well as the relative productivity of different fisheries (section 5.5.8).
- CF or mass fishing occurs when CPUE is high, but many villagers, especially women, like it because it is quick and efficient, i.e. water quality will be swiftly redeemed for bathing and domestic purposes (the turbidity caused by entry to the tank for fishing typically takes a minimum of 5-6 days to decline). From this perspective, increasing fish biomass reduces the overall value of the tank for other uses.

Key informants also revealed the existence of a more commercial access arrangement whereby tank fisheries are rented to small groups of fishermen, who gain exclusive rights to harvest the tank, usually after irrigation requirements have been met. The practice is restricted to smaller isolated 'private' tanks where (1) irrigation rights are the preserve of a limited number of individuals, (2) there is a low reliance on the tank for ancillary functions such as bathing (3) tanks are small enough to ensure high CPUE with minimum manpower during the dry season. The fishermen also guard the tank from poachers thereby shielding the owner(s) and other locals using the tank for bathing from more protracted conflicts with bathers and irrigators (Chapter 2). Such 'rentals' are only common when rainfall has been high, leading to the spillage of seasonal tanks. Such events encourage migration and natural restocking of the higher more seasonal water bodies by fish lower in the watershed (Chapter 2). Adverse rainfall conditions meant that no such access arrangements were reported during the year 2000. These findings indicate well developed local knowledge relating to natural recruitment.

Direct observation of two impromptu mass fishing events, which included yield measurements, took place in Ankendawewa (ANK) and Lokahettiyagama (LHG) in the Giribawa research area.

ANK is an 'axial 2' tank, belonging to an (upper) *goyigama* caste community (Chapter 4), inundating approximately 6ha at maximum water-spread (MWS). Located at the margin of a *purana* complex incorporating four tanks, this water body was exposed to heavy external and internal poaching as the dry season progressed. Consequently, when water levels fell to below 0.3ha and 1m maximum depth and a fish kill also appeared imminent, four days of intensive fishing were sanctioned resulting in almost complete harvest of resident stocks.

A total of 73 people participated over the four day period. Thirteen came from the immediate community and sixty from five neighbouring villages (all *goyigama* caste) with whom reciprocal informal access arrangements existed. Numbers decreased after the first day, which yielded more than two thirds of the total harvest, while restrictions on outside participation were simultaneously eased. A small number of approximately 15 youth, who had initiated the activity through their 'poaching', persisted longest. The final day culminated with mud-fishing. This involves sectioning of the residual water-spread into smaller areas by constructing shallow mud dykes making the remaining stocks easier to catch. Gill nets (mostly between 3.8 and 5.1 cm) were supplemented with a small number of traditional wicker '*karaka*' traps, which operated more efficiently under shallow confined conditions in which the remaining aquatic weeds were also being concentrated.

The intensive fishing resulted in elevated turbidity, which combined with rapidly shrinking residual water storage, effectively precluded any further bathing prior to the onset of the next rains. However, as the villagers also had access to a larger, central tank in which fishing was more closely regulated, most participants and non-participants questioned, regarded this curtailment of amenity in Ankendawewa as an acceptable compromise.

Over the entire period, approximately 310kg of fish was harvested consisting of 61% snakehead, 29% tilapia, and 10% other small indigenous species. This was equivalent to a yield of 102 kg ha^{-1} (50% MWS) and an average return of approximately 4kg per participant, and was reported to be a fairly average yield in comparison to previous years. Interestingly the predominance of tilapia and snakehead in the catch was reported to fluctuate regularly, with greater overall yields associated with 'tilapia years'.

The abundance of commercially valuable snakehead combined with the proximity of the tank to a nearby commercial fishery also attracted the attendance and participation of two local commercial 2-wheeler vendors. Consequently, '2-wheeler' and informal vending, i.e. by young fishers within their respective communities, accounted for nearly one quarter of the catch. The balance was directly used for household consumption in fresh or dried form.

LHG an 'axial 1' tank, of 13.1 ha (FWS) was one of the tanks selected for phase 2 trials (section 5.6.1). Villagers here regularly practiced lift irrigation, using pumps supplied by an NGO (Chapter 4), to exploit residual 'dead' storage. Consequently, two weeks of informal collective fishing had taken place during the previous year with almost complete loss of standing stocks as the tank dried to muddy pools. Although no spill events had subsequently occurred, an inland fish bicycle-vendor resident in the village had released several plastic bags of mixed fry (mostly tilapia), obtained form nearby Rajangane Reservoir on his own volition.

Later that year, farmers again resorted to lift irrigation, the water situation became equally critical (0.3ha and 0.5m max depth) and village officials planned to conserve the remaining water for bathing; this being the only suitable tank in the village. However, large livestock entering the tank for drinking and wallowing had significantly reduced water quality. These conditions prompted exploratory fishing by one villager adjacent to the tank. Word spread rapidly, resulting in an impromptu collective fishing lasting three days.

Consistent with the expected low level of fish stocks in the tank, participation was sporadic, low level and entirely internal to the village. A total of 18 people participated over the three days (in a village containing 47 households) which culminated with mud-fishing undertaken by three village boys and one adult, now in muddy ankle-deep water. Bathing was subsequently restricted to a number of shallow wells, excavated around residual muddy pools, by those living close to the tank, while most other villagers relied on agro-wells or external water resources adjacent to the village.

The total measured yield consisted of 52kg of tilapia, and almost 5kg of small indigenous species (SIS); mostly climbing perch (*Anabas testudineus*). Although equivalent to a yield of 3.2kg per participant, highest returns came early on the first day, with CPUE decreasing from 0.89 to 0.24 kg person^{-1} hr^{-1} by the third day. In terms of net productivity, the yield amounted to only 8.7 kg ha^{-1} (50% MWS), considerably lower than ANK, but consistent with its previous hydrological and fishing history.

Triangulation of CF yield measurements in ANK and LHG with key informant estimates indicated a tendency for significant over-reporting. Consequently, little reliance can be placed on yield estimates in the 18 additional tanks where harvesting took place (data not shown). The smallest radial tanks were perhaps the exception, i.e. typically, fishing was brief, intensive and yields low enough for observers to gain a better overview. Yield estimates in the three tanks in this category (all less than 3ha at MWS) were very low ranging from 20 – 45kg (7-15 kg ha^{-1} at 50%MWS).

The upper estimates in each spatial category provided a useful benchmark for assessing intervention tank outcomes, i.e. ranging from 15 kg ha^{-1} to 100 kg ha^{-1} in radial and 'axial 2' tanks respectively.

5.2.2 Adaptive strategies: current enhancement activities

During the course of the extended situation analysis, it became apparent that in some villages activities designed to enhance standing stocks were already in use, albeit at a low and informal level. Two types of activity were identified; the first involved the overcoming of impediments to natural migration, and the second, the transfer of juveniles and adults between adjacent tanks (i.e. stocking based on wild sourcing).

Wild sourcing was practiced by a variety of different groups, in the most seasonal tanks subject to frequent drying. Children fishing in perennial water bodies frequently release juveniles back into their own village tanks. Some of those involved in regular subsistence or recreational fishing moved juveniles and adults, mostly tilapia and snakehead, from the same sources in a more purposive fashion. Finally commercial bicycle-vendors would occasionally transport small numbers of juvenile tilapia in plastic bags, sourced from their supply tanks back to their home villages (as in LHG - section 5.2.1).

'Migration enhancements' were practiced in intermediate-sized tanks, typically axial 2 or larger. Such tanks, while small enough to encourage periodic intensive collective fishing (and the subsequent depletion of standing stocks), were also large enough to have sizeable permanent concrete weirs installed. These weirs allow more water to be safely stored, but block or inhibit upstream migration (Chapter 2). Consequently, during spill episodes villagers were occasionally observed placing makeshift 'fish ladders', usually plastic, metal or wood half pipes, against weirs; permitting the passage of fish trapped below (Plates 5.2 A and B). Spill events also attract a significant amount of fishing activity, usually concentrated in the area immediately below weirs. While larger fish are selectively harvested, substantial numbers of juveniles caught in fine mesh traps are frequently returned to the water above the weir.

Plates 5.2 A and B: Ankendawewa, April 2001: (A) local villager improvising a fish ladder below a culvert weir, using a length of tree bark (B) a simple improvised barrier trap, positioned in the spillway below the weir (owner displays a gouramy caught in the trap – many smaller fish were returned above the weir)

Such periodic activities typically occur on a highly *ad hoc* individual basis. Those living close to the tank or its surplus weir were more likely to participate. While it proved extremely difficult to enumerate the occurrence of such events through stakeholder forums or key informant interviews, direct observation indicated that these practices probably make a significant contribution to maintaining production in upper-watershed areas; particularly during sequences of drought years. Consequently, the second phase of trial interventions was based on an adaptation of these practices, under the hypothesis that this would be more likely to yield a sustainable outcome than reliance on hatchery-produced juveniles for stocking purposes.

5.3 Stakeholder analysis

The outcomes of secondary and primary stakeholder workshops are summarised in the following sections. These were held at the outset of the research in order to formulate a participatory research agenda. The 'secondary' workshop, involving government, development and academic staff, was held in an urban setting (Kandy), while multiple primary workshops with farmers were held in Dry-Zone villages with potential to become intervention sites. The methodology is described in Chapter 3 and a fuller description of the stakeholder approach and outcomes of the secondary stakeholder workshop are reported in Murray and Little (2000e).

5.3.1 Secondary stakeholder workshop outcomes

Despite a broad range of constraints and knowledge gaps identified by secondary stakeholders, results still reflected a technical bias associated with the stocking of hatchery-produced exotic carps. Many stakeholders, in the government, NGO, and research sectors, continue to promote their use despite the failure of many previous initiatives. In this respect, lack of sufficient and timely seed availability, was cited as one of the main constraint to sustainable adoption of culture-based stocking systems.

Three major questions arise from this contention: (1) even if sufficient fish seed were available at the right size and time, would they lead to measurable impacts on production, given the significance of other largely unmanageable and highly unpredictable constraints, e.g. predation, aquatic macrophyte encroachment, seasonality etc.? (2) Would increased production be significant, set against potentially high back-ground production levels of self-recruiting tilapias with which carp management systems may be incompatible? (3) In turn, would benefits of increased

carp production accrue to poorer people within communities? These are the main questions addressed in this and the remaining chapters.
Many of the socio-economic criteria identified, also reflected the bias towards culture-based stocking, i.e. secondary stakeholders were essentially focused on the need to exclude external participants as anti-social elements, rather than attempting to engage them as potential beneficiaries. Results presented in this and Chapter 6, indicated that those accused of 'poaching' included those most reliant on the resource for their subsistence.

During the course of formulating a research agenda, the stakeholders identified many of their own weaknesses. For instance, while academic participants pointed out the need for coordinated basin level hydrological management, all those involved in an implementing capacity conceded that planning tank rehabilitation rarely extended beyond the immediate community level. Academics in turn were challenged by field researchers and development workers as to the relevance of their research foci and knowledge of real issues facing poor communities. The current lack of effective extension and research services towards improving fish production was linked not just to resource limitations, but also to conflicts of interest and lack of communication between government agencies. The limited capacities of these organisations to promote change and enforce laws were acknowledged as major constraints to strategies based on co-management.

Other technical options suggested included rice-fish and ornamental culture. These were discounted as poverty-focused options due to technical and marketing constraints cited elsewhere (Murray and Little 2000c).

The knowledge gaps and constraints highlighted in Appendix 32 were ultimately deemed as being amenable to research, and consistent with the poverty focus of our research framework. This selection was based on a combined assessment of these results, together with findings from primary stakeholder workshops, other field investigations and secondary data review.

5.3.2 Primary stakeholder workshop outcomes

Many of the outcomes from primary stakeholder meetings have been discussed in previous sections. Other findings with relevance to low-input fisheries enhancements are presented below.

Watershed perspectives: The significance of barriers to migration arising from selective tank rehabilitation, poorly designed surplus weirs, and encroached spillways (Chapter 2), only emerged after protracted situation analysis. No local awareness of this problem was evident at either the primary or secondary stakeholder level (section 5.3). However, direct observation revealed numerous instances where farmers took simple steps to circumvent migration obstacles (section 5.2.2); though there were no instances of farmers taking direct steps to improve the survival of stocks during the dry season, i.e. through excavation of fish refuges.

Self-recruiting food species: At least twenty five reservoir fish species were identified as having at least occasional food value. Respondents in Gurulupitigama (GUR), the intervention village with the largest tank (Appendix 16), and most varied resident fish population, identified 22 different inland species; 17 of which were reported to occur in their tank. Of these, 16 were occasionally consumed (Appendix 33). The one remaining variety *Aplocheilus parvus* (dwarf panchax), known as *thithi* is used as a bait fish. Less than half the total number of species recorded in GUR were reported in the most seasonal upper-watershed tanks; the five most regularly consumed varieties observed during this study are shown in Plate 5.3.

Harvesting strategies: Of the 24 PCs investigated during the watershed phase of the study (Chapter 2), three had direct experience of carp stocking in at least one of their village tanks (Tatawewa and Pahala Diulwewa in the Anamaduwa area and Kumbukwewa in the Giribawa area). None had proved sustainable due to technical and social problems discussed elsewhere. Nevertheless, the production potentials which were demonstrated in the early years of these schemes had fostered a strong desire for income-generation systems based on single intensive harvesting. This was re-enforced by a strong conceptual bias associated with agricultural production systems, and a dependency culture, whereby development interventions are associated with tangible and immediate financial benefits.

Plate 5.3 Five of the most important food fish varieties naturally occurring in seasonal village tanks; clockwise from top left; tilapia (*Oreochromis mossambicus*), climbing perch (*Anabas testudineus*), snakeskin gouramy (*Trichogaster pectoralis*), *Puntius* spp. (the lower example shown here is the swamp barb - *Puntius chola*), Snakehead (*Channa striata*)

Advanced stocking: As noted above, many respondents envisaged that predation levels would be extremely high if tanks were stocked too early, i.e. while retaining only shallow residual water-spread. Once again, this perception was heavily influenced by familiarity with the stocking of hatchery-produced carps rather than self-recruiting tilapias.

Pasture improvements: Most primary stakeholders were indifferent, or rejected outright the idea of improved pasture management as another potential enhancement strategy. This was attributed on one hand to relatively low levels of livestock holdings associated with low pasture availability, and on the other, to the increased the risk of conflicts related to tank incursions and crop damage.

Poorer households, who kept small numbers of cattle for subsistence purposes, were most likely to leave their animals unsupervised to graze around local village tanks. These households were also likely to have lower land holdings and less interest in irrigated cultivation under the same tanks. Conversely, the few better-off households with livestock were more likely to graze their larger herds on extensive pastures in lower-watershed areas, often under hired supervision. Consequently, there existed a clear conflict of interest between poorer livestock owners and cultivators which emerged as the principle for reason for the rejection of this option. Furthermore, our study of seasonal nutrient dynamics (Murray 2004b), demonstrated the increasingly mesotrophic status of smaller, shallower tanks; other constraints, including erratic recruitment and high predation levels, were therefore deemed as being more critical constraints to increased fish production.

Section 2. Action-research strategies and outcomes

Two phases of action research were initiated between 2000 and 2001. A total of nine tanks (one of which was stocked twice), belonging to six communities, were stocked in Anamaduwa and Giribawa research areas (Table 5.4 and Figure 5.9). Site selection was based on poverty criteria, community willingness of to participate and access to tank resources likely to hold water for at least 7-8 months. The outcome of phase 1 trials contributed to the iterative design of the second phase.

Phase 1 trials incorporated a more heterogeneous range of communities in terms of watershed location, community size (10 – 104 households) and caste composition. Based on the results of these trials, participation in phase 2 was restricted to smaller-sized (25 to 51 households), lower-caste communities accessing smaller seasonal tanks in upper-watershed areas. Hatchery reared *O. niloticus* juveniles were stocked in phase 1, while a range of locally-sourced wild varieties, including tilapia and snakehead, were utilised in phase 2. Despite the interest expressed by many farmers, carp-based stocking was discouraged throughout due to a low likelihood of sustainable adoption and a questionable poverty focus, indicated by the outcomes of many earlier trials (Chapter 1).

There was also a marked difference in rainfall levels during the two trial phases, with implications for the baseline fish population levels and harvesting strategies. The year 2000 was the driest year for 8 and 13 years in Anamaduwa and Giribawa respectively. Conversely, 2001 was the wettest for 10 and 8 years and experienced a reversal of the conventional bi-modal distribution of rainfall between the NE and SW monsoons (Chapter 2). Annual rainfall levels in 2000 remained close to the 75% probability level of rainfall at which tanks are designed to spill. Consequently, poor fish migration potential, combined with high levels of drying during this and the previous year meant that natural fish population levels at the onset of both trial phases were extremely low in non-perennial tanks (Chapter 2). Prior to any stocking, key informants were consulted and test fishing undertaken (using ¼” cast and fine mesh hand nets) in any areas of residual storage to assess whether any resident fish population remained.

The rehabilitation status of tanks (with respect to de-silting), also proved to be a significant variable in terms of the status of resident populations, grow-out potential for stocked fish and CPUE characteristics.

All three communities participating in phase 1 trials elected to restrict fishing, until decreasing water levels permitted intensive collective harvesting events to be staged during the dry season. Revised phase 2 hypotheses, based on intermittent/ staggered harvesting, are presented in section 5.6.3. The two phases also differed fundamentally in the nature of monitoring systems used to evaluate impacts (Chapter 3).

5.4 Phase 1 researchable hypotheses

Phase 1 trials were used to test the following research hypotheses (RH), based on results of the initial situation analysis (Chapter 1: Table 1.4) Hypotheses are presented after a brief statement of relevant background knowledge.

In Sri Lanka, the following conditions are commonly found around seasonal tanks:

- There is a traditional seasonal subsistence fishery, but no indigenous tradition of aquaculture.
- In the most seasonal tanks regular disruption of natural fish recruitment occurs, necessitating periodic restocking.
- High yields are possible from culture-based enhanced fisheries in seasonal tanks, with no requirement for additional fertilisers or supplementary feeds.
- Highly erratic water availability and high predation pressure are attributed as the main causes of the wide yield fluctuations between successive crops, observed in earlier trials.
- Limited technical, extension and private and public seed production capacity compounded by an opportunity cost for ornamental fish production, continue to be major constraints to uptake of culture-based fisheries in seasonal tanks.
- Conventional hatchery based restocking programmes devolved to a community level continue to be the favoured approach of development institutions in Sri Lanka. Although such programmes can work technically, they have not been shown to be sustainable, and their impacts on poor local people have not been demonstrated.

In this context, greater research emphasis should be placed on low-cost enhancement systems, which aim to increase or sustain existing production levels in the face of increasing environmental pressure. Stock enhancement requires a cost-effective means for mass production of young fish. Ideally suited to this role are naturally recruiting and locally available tilapia species. Tilapias have the ability to grow rapidly in short seasonal growing periods and are tolerant of extreme water quality fluctuations common in seasonal tanks.

A simple method of ensuring an adequate seed supply is to stock breeding tilapia and control predation pressure early in the season. This strategy is likely to work best in tanks that dry out and where as a result, densities of predatory fish such as snakehead are low. Subsequently, fingerlings of a suitable size might be used to stock less seasonal tanks where predation will be concentrated on their offspring. Previous studies in Sri Lanka have demonstrated that natural productivity is inversely related to reservoir surface area (Chapter 1). Thus accelerated growth could also be achieved by producing advanced fingerling in the smallest tanks. Communities in the mid to upper watershed may have access to both small and intermediate sized tanks suitable for *in situ* fingerling production and on-growing respectively. Based on this reasoning, our preliminary hypotheses envisaged fish movements in a tilapia-based, enhanced fishery with horizontally integrated seed, grow-out and broodstock components demarcated at the watershed level (Appendix 30).

The following research hypotheses are consistent with these observations. Hypotheses are prefixed as first (I) or second (II) order hypothesis. First order hypothesis represent the most extensive, simple and lowest risk interventions which should be tested before or independently of second order hypotheses, which seek to further enhance production systems and marketing networks.

1. Intra and inter-community linkages:

- A1.1. (I) Could advanced fingerlings be grown in small highly seasonal tanks kept free of predators, if mature tilapia broodstock sourced from larger perennial tanks are stocked at the onset of the NW monsoon?
- A1.2 (I) Could stocking of seasonal tanks with advanced fingerlings overcome the problems of poor survival and erratic water availability experienced in early trials?

- A1.3 (II) Could communities with access to perennial tanks be encouraged to trade broodfish to those with seasonal tanks requiring them early in the season?
- A1.4 (I) Could informal access to fisheries in perennial water bodies be negotiated for fishing groups from upper-watershed areas in return for collective services such as the clearance of *salvenia* or bund vegetation?
- A1.5 (I) *Sustainability:* Could aquaculture options based on low input-output stocking strategies relying on locally sourced seed, enhance social capital, cohesion and water management at the village and wider watershed level?

2. Harvesting strategies:

Production in seasonal tanks is usually concentrated over the two months at the end of the dry season (Jul – Aug), when supplies from the major reservoir fishery are also at a maximum and prices are at their lowest seasonal level. Poorer farmers are more likely to purchase smaller tilapias (100g – 200g), being less costly than larger 'table-size' fish. The smallest specimens (<100g), are more likely to be sold as dried fish. Dried fish is relatively more important to the protein intake of poorer groups, but represents a salvage rather than a value addition marketing pathway (Murray 2004b).

- A2.1 (I) *Productivity:* Could staggered harvesting strategies sustain greater yields, higher market prices and hence increase profitability?
- A2.2 (I) *Equitability*: Could staggered harvesting strategies bring indirect benefits to poorer consumers through increased production of smaller, more affordable fish through much of the year?

5.5 Phase 1 stocking interventions

5.5.1 Phase 1 site selection

As a pilot exercise, phase 1 trials incorporated a wide range of physical and social settings (Table 5.3). Five tanks ranging in size from 0.89ha to 25.9ha (FSL) belonging to three communities in upper and lower-watershed positions were finally selected and stocked. Two of the communities ULP (Ulpathwewa) and GUR were low caste. IMK (Ihala Maradankadawala) although an upper caste village, like ULP, was located in an upper-watershed area. Details of the selection process are given in Chapter 1. The number and size of tanks that could be stocked was also constrained by an extremely limited supply of hatchery-produced juvenile fish stocks.

The two larger communities, IMK and GUR (> 100 households), each had access to smaller radial tanks (18 and 3 respectively); ranged around a larger axial 'base' tank. The satellite tanks were surrounded by some of the poorest households in the village (Chapter 4). However these same groups felt that priority should be given to the larger axial-'base' tanks for the following reasons:

- Priority was given to bathing and drinking functions in certain strategically located tanks for outlying sections of the community during the dry season.
- Where irrigation rights rested with parties resident in the main village, rather than those in close proximity to the tank, rights of access for secondary production functions such as aquaculture were less certain.
- Greater difficulties protecting isolated outlying tanks from poaching.
- Reluctance to assume management responsibility independently of the other village institutions; namely the FO which also lobbied for the stocking of the largest tank to 'benefit the wider community'.
- Latent expectations associated with carp stocking, which excluded smaller tanks.

Consequently, the selection finally incorporated three radial tanks; two in ULP and one in IMK as well as two larger axial tanks in IMK and GUR. This combination also meant there was potential for investigation of the stock movement hypotheses (RH A1.3; section 5.4)

To avoid confusion, tanks are hereafter distinguished by the addition of a superscript to their abbreviation where it is necessary to distinguish them from the villages bearing the same name, e.g. IMK^t refers to Ihala Maradankadawala tank. The locations of phase 1 and 2 intervention tanks within the Giribawa area are shown in Figure 5.1.

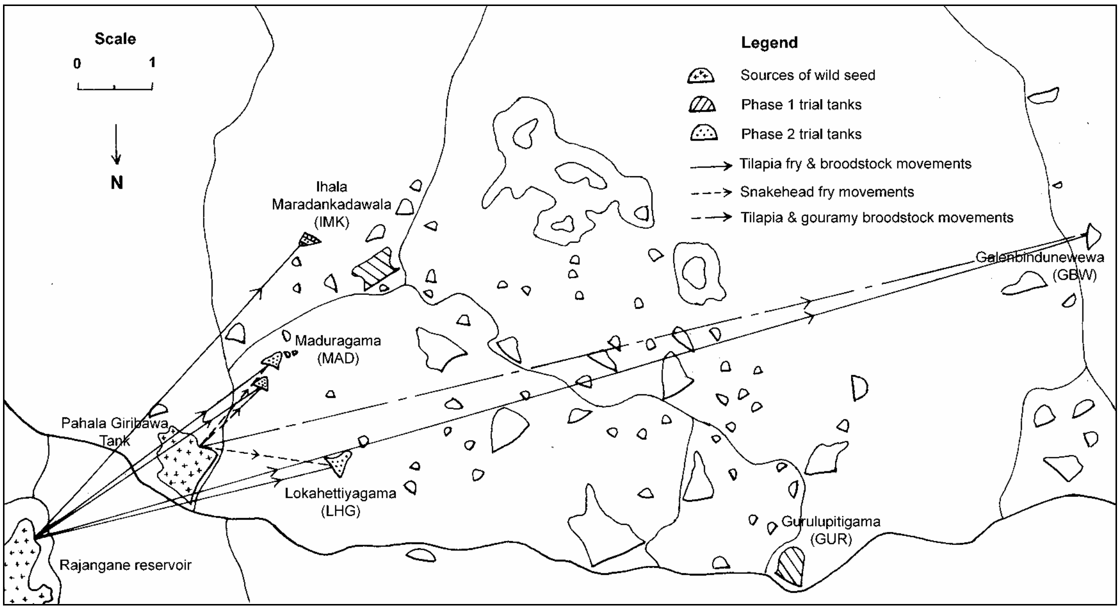


Figure 5.1 Location of tanks stocked in phase 1 and 2 trials in the Giribawa research area', Feb 2000 – Nov 2001; and sources of wild-caught seed used in phase 2 trials.

5.5.2 Baseline survey of phase 1 tank production characteristics

In order to evaluate intervention outcomes, data relating to baseline production characteristics were collected prior to stocking (Chapter 3). Results are summarised in Table 5.3. A sequence of three progressively low rainfall years was responsible for the generally low level of standing stocks detected in the CF baseline survey (section 5.2.1). These conditions resulted in depletion of the smallest, most seasonal tanks first, while intermediate sized tanks like IMK and GUR appeared to temporarily benefit from an increase in CF yields. This was associated with increasing CPUE as dry-season storage residuals fell to their lowest levels for many years.

Various other tank management activities also had important production consequences. Recent de-silting works necessitated complete drying and entire loss of resident fish stocks in three of the phase 1 tanks. Mechanised de-silting entailed removal of the entire tank bed silt layers from the two smallest tanks, in ULP, during the year prior to stocking. Villagers reported that they had stocked a small number of tilapia juveniles and snakehead to initiate re-population, though none were revealed during test fishing.

IMK^t had been partially de-silted and simultaneously intensively harvested, four years previously. In both IMK^t and GUR^t, natural repopulation was inhibited by the construction of stone and concrete surplus weirs (with vertical drops of over a 1m - Chapter 2). These barriers blocked the major migration routes from lower perennial tanks. Nevertheless, natural recruitment from some of the upstream tanks around IMK, combined with physical transferral of fish trapped below the weir during a subsequent spill event, appeared to have promoted the recovery of standing stocks. Villagers reported that yields were once again approaching pre-rehabilitation levels, based on the previous year's collective harvest. The relatively low spill frequency of the two larger axial tanks (1:5 years) indicates that repopulation of such tanks post rehabilitation, could be substantially delayed without some level of re-stocking.

De-silting activity had two other further consequences for fish yields through its impact on nutrient status and fishing effort. Partial de-silting invariably involves deepening of the area adjacent to the bund. In IMK^t this inhibited re-colonisation of the area by aquatic macrophytes (Appendix 22) which in turn increased collective harvesting efficiency compared to GUR (section 5.6.8). The adverse effects of de-silting on nutrient status in ULP^t and Keeriyagahawewa (KRG – Chapter 2: Plate 2.3) are discussed below.

Test fishing revealed the greatest diversity of fish species in the largest axial tank, GUR^t (Appendix 33). In addition to tilapia and snakehead, other small indigenous species (SIS) included *Puntius* spp. *Mystus* spp. *Rasbora* spp. *H fossilis* and *T. pectoralis* (Table 5.3). The first five of these species were also detected in IMK^t. The use of residual dead storage in Serugaswewa (SER) for irrigation in 1999 also resulted almost complete depopulation. Test fishing revealed the presence of only two hardier varieties, *A. testudineus* and *Mystus* Sp., which appeared to have persisted in pools sheltered by an area of inaccessible scrub forest.

Table 5.3 Baseline production characteristics of phase 1 intervention tanks

Village name	GUR	IMK		ULP	
Research area[1]	**GIR**	**GIR**		**AMD**	
Caste[2]	***Paduvua***	***Goyigama***		***Badahala***	
Tank name[3]	**GUR**[t]	**IMK**[t]	**SER**	**ULP**[t]	**KRG**
Spatial class	Axial 3	Axial 2	Radial	Radial	Radial
No Households	119	107	21	10	
Irrigation Maha 99	N	N	N	Y	Y
Irrigation *yala* 00	N	Y	Y	Y	N
Irrigation *maha* 00	N	N	Y	Y	Y
Year of last rehabilitation activity	1997	1997	1995	1999	1999
Type of rehabilitation activity[4]	HW	HW, PD	HW	HW, CD	CD
Last year tank completely dried	NA	NA	1999	1999	1999
Reason for drying	NA	NA	Lift irrigation	De-silting	De-silting
Drying frequency over last 5 years	0	0	2	1	5
Spill frequency over last 5 years	1	1	5	4	4
Last year of spill linkage	1997	1997	1999	1998	1998
Surplus weir migration potential?	None	None	High	High	High
Last year of collective fishing	1999	1999	1999	1998	1998
Species indicated by test fishing Jan 00[5]	T,S,H,P,M, C	T,S,P,M, C	M, C	none	none

1 GIR = Giribawa, AMD = Anamaduwa

2 *Paduvua* = Palanquin bearer, *Goyigama* = Farmer, *Badahala* = Potter

3 KRG = Keeriyagahawewa, ULP = Ulpathwewa, IMK = Ihala Maradankadawala, GUR = Gurulupitigama

4 HW = Head-works (repairs to bund, sluice and surplus weir), PD = Partial de-silting, CD = Complete de-silting.

5 T = *Oreochromis spp.*, S = *Channa striatus*, H = *Heteropneustes microps*, P = *Puntius* spp, C = *Anabas testudineus*, M = *Mystus* spp.

5.5.3 Phase 1 stocking strategies

Due to lack of familiarity with wild-sourcing options at this early stage, phase 1 trials were based on the stocking of hatchery-produced *Oreochromis niloticus*, though there was a possibility that this stock had been contaminated and hybridised with wild *O. mossambicus*. Advanced juvenile fingerlings, 2-20g, were procured from a former government hatchery contracted by the provincial administration to retain a limited amount of food fish production capacity. Stocks were packed in plastic bags, oxygenated and transported in the morning when temperatures were cooler. Journey times were no longer than two hours. These favourable conditions meant that transport losses were minimal, i.e. no more than 1-3%. Seed shortages and bureaucratic delays were the primary factors which limited the number of tanks that could be stocked in this phase. Participants from each village accompanied the fish from the hatchery and supervised their release (Plates 5.4 A and B). Stocking densities ranged from 842 (ULP[t]) to 337 (KRG) fingerlings/ha at 50% MWS area (Table 5.4). Although these rates were relatively low (due to seed availability constraints), their advanced size was likely to have resulted in improved survival.

During both trial phases, many smaller tanks almost dried again after promising, but intermittent early NE monsoon rains and farmer fears of losses to predation (especially birds) seemed well founded. Consequently, in phase 1 the intention was to stock tanks during the pre-spill period, but only once dead storage levels were surpassed. Ultimately, difficulties obtaining hatchery produced seed meant that tanks were almost half full by the time they were finally stocked. This represented a loss of at least 4-6 weeks of potential grow-out time.

Table 5.4 Summary of phase 1 tank stocking activity in Anamaduwa and Giribawa research areas, 2000

Village name	**GUR**	**IMK**		**ULP**	
Tank name	**GUR[t]**	**IMK[t]**	**SER**	**ULP[t]**	**KRG**
Date stocked	16 Feb	8 Feb	8 Feb	29 Jan	29 Jan
Surface area at MWS* (ha)	25.9	18.1	3.25	2.02	0.89
Surface area at 50% MWS	12.95	9.05	1.54	1.01	0.445
Total O. niloticus juveniles stocked	7000	4,500	1,000	850	150
Stocking density (fish/ha 50%MWS)	541	497	649	842	337
Weight range (g)	3-20	3-14	3-14	2-15	2-15
Weighted mean (g)	9.2	7.3	7.3	6.9	6.9

* Maximum water-spread obtained at full supply level (FSL)

A

B

Plates 5.4 A and B: Members of GUR fishermen's society, stocking hatchery-produced *O. niloticus* juveniles (A) in GUR tank (B) - February 2000

5.5.4 Phase 1 management strategies

Prior to stocking, meetings were held in each village to formulate collective management strategies designed to ensure equitable distribution of any enhanced yield and the sustainability of the enhancement practice (section 3.2.1.3). Topics for discussion included: (1) rules pertaining to fishing rights and restrictions, (2) communication mechanisms, i.e. by which broader participation might be encouraged and decision outcomes disseminated (3) rule enforcement and conflict / mitigation /

resolution mechanisms. One final activity concerned resource mobilisation; in the absence of any financial commitment, this involved allocation of individual and institutional responsibilities to undertake the aforementioned activities.

Villagers were encouraged to come to some preliminary agreement on these issues before the trials began; operational rules would then be subject to periodic review based on interim results. In this way, it was hoped that iterative experimentation with the rules would become a key component of the management process. Results are summarised below.

Although the possible benefits of staggered harvesting were proposed by the research team, each community decided to adhere closely to the 'traditional' management precedents. In order to avoid water-use conflicts (with bathing and irrigation), bans would be imposed and harvest restricted to brief collective fishing events during the dry season. Consequently, management would entail to two main activities (1) guarding the tank(s) from poaching towards the end of the grow-out season (2) organising collective fishing and yield distribution.

In the large communities, responsibility for tank guarding was initially demarcated to fishing societies (FG), formed as sub-committees of existing farming organisations. These societies were formally constituted with executive officers and registered with the local administrative authorities. In return for their efforts, members would either be given priority on the first days fishing (IMK), or be entirely responsible for fishing and distribution of the catch, for which they would receive an additional share. If sufficient stocks were harvested, a portion would also be used to raise income for tank maintenance thereby benefiting other water users. In ULP, which consisted of only 10 households belonging to one extended family (Chapter 4: section 4.3.3), a much more informal arrangement was envisaged. Here the whole community would be directly involved in flexible decision making through their close daily association.

Ultimately neither of the constituted fishing groups functioned effectively. This was due to a lack of tangible collective functions and responsibilities, particularly during the early part of the grow-out period. Also, risk of detection by those living adjacent to the tank, including the FO President in GUR, proved sufficient deterrence to all but the most determined (night time) poachers using gill nets. Because ordinary membership was not contingent on reward but no clearly defined responsibility over half of all households subscribed to the FS in the two largest villages, GUR and IMK. This made decision making extremely difficult, particularly as many of the registered members failed to attend meetings. Although membership rates were even higher in the smaller villages, where most households registered, the smaller number of households meant that informal communication and organisation was much more straightforward.

In IMK no action was taken to remedy this problem, while in GUR the situation was reviewed and an alternative strategy adopted. Here, eligibility to participate in collective fishing, or alternatively to receive a share of the catch, would be contingent on a household member participating in a *Shramadana* activity (community service – Chapter 4: section 4.3.10) which involved clearing encroaching aquatic macrophytes from the tank. Two years earlier, *Salvenia molesta* had been transferred from a nearby tank by fishermen using contaminated nets. Thereafter, it spread rapidly to cover all but the deepest areas of the tank. This presented particular problems for bathers, but also reduced primary productivity and thereby fish growth and harvest potentials.

The event was held in June, when water levels were low enough to permit wading over the entire area of the tank to concentrate the weed. Submerged weeds and other obstacles such as stones were removed simultaneously. Some 83 villagers participated, 60 of whom had earlier registered in the fishing society. This compared to 50-60 participants in two earlier *Shramadanas*. The high turn out was due to successful incentivisation, combined with a concerted joint effort by various village institutions to encourage participation. The local *Grama Niladhari* (GN) also visited households prior to the event and subsequently registered attendance; furnishing the FO with a list of absentees.

Interestingly, women, who were culturally excluded from fishing, participated alongside men in the *Shramadana*. The system also provided an assured means of female headed households with no male representation receiving a share of the collective fishing harvest. Although no wealth enumeration took place, key informants reported that participation was confined to poor and medium wealth households, i.e. sanctions against non-participation did not unduly concern better-off households.

Participants divided into two groups and worked from opposite ends of the tank. This divide reflected an inter-generational split between younger males and more conservative elders in the village described in Chapter 4. The *Samurdhi* extension officer was a charismatic young man who coordinated the youth group while the FO was headed by more traditional villagers. However, by and large both groups were able to cooperate effectively and their differences although recurrent, were not a serious source of conflict in the village, both prior to and after the intervention. The event lasted six hours, during which time around 75% of the Salvenia cover was cleared (being left to dry and decompose along the side of the bund). The clearance culminated with a social event; food and drink was provided by the FO and alcohol was discretely shared amongst the youth group.

In IMK, political divisions resulted in poor capacity to organise effective collective fishing in the base tank, IMK^t. The intervention culminated in an unorganised mass fishing event and although substantial yields were harvested, benefits were outweighed by conflicts between those participating (section 5.5.9). Such divisions were less of a problem around three other radial tanks in the village where collective fishing also took place. These sites had the benefit of smaller numbers of stakeholders combined with the strong informal leadership of prominent older, male land-holders living close to the tanks.

Unfortunately the dependency attitude fostered by previous development efforts in ULP (Chapter 4), one of the poorest villages, was at odds with goals of the project and proved a serious constraint to collaborative research. However, ultimately technical problems associated with recent tank de-silting (section 5.5.2) resulted in the failure of interventions in both ULP tanks (section 5.5.5).

5.5.5 Phase 1 collective fishing management and production outcomes

CF events took place between July and August. A total of six days collective fishing were recorded consisting of 3, 2 and 1 days in GUR, IMK and SER respectively. As in the baseline study, tanks were harvested in order of size; the smallest tank (SER) being harvested three weeks prior to the largest (GUR). Rising internal and external poaching was a factor in the initiation of CF events in all tanks, but most especially in IMK^t where a high level of internal dissension persisted over access arrangements. In

SER, CF was initiated after the principle land owners under the tank decided to carryout emergency lift irrigation with the residual dead storage. This prompted a short period of highly intensive fishing by other villagers, resulting in complete harvest of the fish population.

Exploratory fishing in ULP[t] and KRG indicated very low yields. Numbers caught were extremely low, small in size (<40g) and these fish had a ‘pinhead’ body conformity indicative of sub-optimal nutrition. This was attributed to extensive de-silting resulting in removal of the entire organic silt layer above the hardpan in the bottom of these tanks (Chapter 3). Consequently, ULP villagers opted to forgo harvesting, in order to conserve the residual storage for bathing. Outcomes in the remaining three tanks are summarised in Table 5.5 and discussed in the following sections.

Table 5.5 Collective fishing outcomes in three phase 1 intervention tanks, Jul – Aug 2000

Collective fishing parameters	Tank name					
	GUR			IMK		SER
Collective fishing date(s)	16 Aug	17 Aug	20 Aug	1 Aug	2 Aug	27 Jul
Organisation	F	F	U	U	U	I
Grow-out period (weeks)	26			25		24.3
No. Local participants	57	21	5	62	21	13
No. better-off participants	0	0	0	2	0	2
No. medium participants	28	10	3	10	5	2
No. poor participants	19	10	5	28	14	9
Wealth rank not collected	10	1	0	22	2	0
No. external participants	2	6	3	18	15	2
No. of fishing groups	17	12	4	29	11	7
No local gears	14	10	3	22	10	6
No external gears	9	4	1	10	4	1
No. gill nets	22	14	2	29	11	4
Mean gill net size (cm)	5.2	5.4	NC	6.5	5.5	5.1
STD gill net size (cm)	1.4	0.7	NC	1	0.9	0
Area at 50% MWS[7] (ha)	13.0			9.1		1.6
Area at DSL[7] (ha)	5			3.5		0.2
Max area at harvest (ha)	2.1			1.4		0.1
Est. macrophyte occlusion (ha)	0.4[2]			0.1[3]		0[4]
Max depth at harvest (m)	1.7			1.2		0.6
Total CF Duration (hrs)	7	5	4	8	4	5½
Mean participants ha^{-1} (at harvest)	28.1	12.9	3.8	57.1	25.7	150
Total Yield (kg)	250.2	28.1	20.5	352.0	87.5	122.5
Area yield at 50% MWS (kg ha^{-1})	19.3	2.2	1.6	38.9	9.6	75.4
CPUE (kg $person^{-1}$ hr^{-1})	0.87	0.18	0.51	0.72	0.17	1.65
Formal redistribution of catch (kg)	26.5	0	0	0	0	0
Mean yield $participant^{-1}$ (kg)	2.9[5]	1.0	2.6	4.4	2.4	8.2
% Yield going to external participants and net-owners	15.1	27.0	36.4	27.5	41.3	14.3
Seed cost as % of retained yield[6]	103.3			144.3		31.1

[1] F = Formal, i.e. regulation based on consensual decision making. U = Unregulated and unrestricted access. I = Informal, i.e. regulated by a small number of influential decision-makers
[2] *Salvenia molesta* and *hydrilla* sp. Concentrated under bund [3] *Nelumbium nuciferum* close to bund
[4] Remaining macrophytes cleared prior to and during collective fishing.
[5] Inclusive of formal redistribution of 26.5kg to an additional 17 non-participant local families
[6] Excluding the portion of total yield going to external participants (advanced fingerlings cost Rs1.5 each - table size tilapia retailed for Rs 50kg at the time of CF)
[7] Other abbreviations: DSL = dead storage level, MWS = Maximum water-spread

5.5.6 Phase 1 mean yield, CPUE and survival

Total yields of 298.8, 439.5 and 122.5kg were recorded in GUR, IMK and SER respectively (Figure 5.2). These yields correspond with mean CPUE of 0.7, 0.66 and 1.65 kg $person^{-1}$ hr^{-1} respectively and production levels of 23.1, 48.7 and 78.6 kg^{-1} ha^{-1} respectively in the same tanks (based on inundated surface area at 50% MWS).

The large difference in CPUE between IMK and GUR on one hand and SER on the other can be attributed to the larger size and residual water-spread in the former tanks. Fishing in SER was most intense in terms of participant numbers and consequently, highly efficient; furthermore, remaining stocks were concentrated into an ever shrinking pool of water as CF and lift irrigation took place simultaneously. Individual effort here lasted only 2.5-4 hours before the fish population was almost entirely harvested. This compared with individual effort ranging between 3.5 - 5.5hrs over successive days in the larger tanks. CPUE also fell rapidly after the first day, due to an interacting combination of rising fish mortality and falling participant numbers (Figure 5.2). Corresponding mean daily yields fell from 4.4 – 9.6 kg person^{-1} on the first days to 1.3 – 2.5 kg person^{-1} on the second. Therefore, little incentive remained for most participants to continue fishing after a maximum of 3-4 days, although substantial fish stocks were likely to have remained in these tanks.

In GUR, low CPUE was compounded by heavy rains several days prior to CF, which increased residual depth and washed a large quantity of *Salvenia molesta* from the shallow foreshore to the deeper bund area. Here it combined with submerged weeds to provide a highly effective fish refuge along the length of the bund. Heavy winds moved this week back to the littoral area several days later, prompting a third day of informal effort by local and external youth on the 20th of August in response to the sudden increase in CPUE.

In terms of overall productivity levels, useful comparisons can be made between CF outcomes in comparable sized tanks during the same year, and in the same tanks over-successive years (Table 5.5 and Table 5.11). All intervention tanks performed favourably relative to similar sized tanks in the baseline study, particularly SER which surpassed all other radial tanks (most of which were depopulated and supported no CF). Yields in IMK and GUR though much higher than LHG, were well below the100 kg ha^{-1} achieved in Ankendawewa (ANK), the highest recorded collective harvest in any of the un-stocked tanks (Table 5.5). This superior performance can be attributed to the favourable size of ANK (6ha) under the prevailing hydrological conditions, i.e. large enough to provide a reasonably large grow-out area but small enough to yield highly efficient CF conditions during the dry season, i.e. comparable to SER.

Although stocking may have sustained production during a bad year, yield improvements were still generally insufficient to meet participant expectations which were strongly conditioned by previous years' outcomes in the same tanks. For example, in GUR where management steps were otherwise highly effective, villagers judged the outcome against a larger yield harvested during the previous year, when residual storage had fallen to its lowest level in many years, facilitating complete harvest. Other possible reasons for under-performance include: sub-optimal stocking densities, relatively short grow-out periods ranging from 5.5 to 6 months, predation, and indeterminate levels of pre-CF poaching, in addition to the removal of silt from two of the tanks.

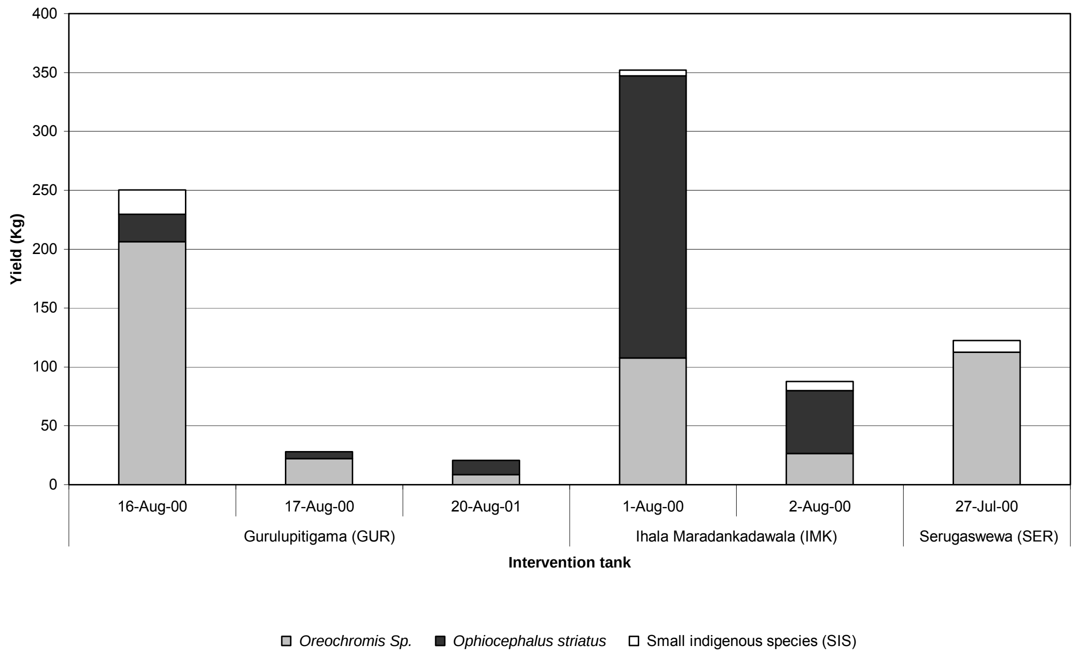


Figure 5.2 Total yields of different fish varieties during collective fishing in three intervention tanks, Jul - Aug 2000

Tilapia constituted 79% and 92% of total yield in GUR and SER respectively, but only 31% of total yield in IMK. Conversely, snakehead constituted 67% of total yield in IMK but only 14% in GUR, where a large proportion of the standing stock was reported to have been harvested during the previous years CF. These reversals could be attributed in large part to the variable fishing conditions and CPUE described above. However a substantial snakehead harvest was also reported from GUR during the previous years CF, indicating that real differences in standing stocks may have also contributed to the outcome. If so, the high snakehead predation in IMK presumably also contributed to the low tilapia yield.

It was not possible to distinguish stocked *O. niloticus* from resident *O. mossambicus*, partly due to limited monitoring capacity, but also because of erratic colour variation (associated with environmental conditions, the time the fish had been out of the water and sexual dimorphism). Therefore, only in SER, where no pre-intervention standing tilapia stock was detected, was it possible to quantify the likely contribution of stocking to yield. Recovery here amounted to 159% of the number stocked (Table 5.6) indicating substantial *in-situ* recruitment. This was also consistent with the relatively low mean weight of fish harvested (71g) and the large number of nesting sites previously observed over the entire littoral of this shallow tank.

Table 5.6 Recovery of *Oreochromis* spp. during collective fishing in three phase 1 intervention tanks

Tank Name	GUR^t	IMK^t	SER
No days collective fishing	3	2	1
Mean weight (g)*	137	129	71
STD Weight (g)*	97.0	77.5	63.2
Total kg	237.2	134.0	112.5
No. recovered	1732	1039	1585
Recovery as % of No. stocked	24.7	23.1	158.5

*Calculations weighted by number of fish within each size category (i.e. large medium or small)

Returns only amounted to around one quarter of the number stocked in each of the larger tanks (i.e. inclusive of standing tilapia stocks); though mean fish weight (129-137g) was considerably higher than SER. These differences are attributable to lower fishing power and higher size selectivity (discussed below), combined with intensive snakehead predation pressure on smaller individuals in the larger tanks. Difficulties assigning provenance together with generally low yield returns and mean fish sizes also meant that no conclusive improvement over and above the performance of wild tilapias could be claimed as result of the use of hatchery reared '*O. niloticus*'.

Other SIS contributed only 5% of the total yield, though under-reporting was a problem as many smaller varieties (<30-40g) were frequently discarded. The highest daily yield was harvested on the first day of fishing in GUR, when a number of smaller mesh-sizes (<5.1cm) were deployed. Over 90% of this yield consisted of *T.*

pectoralis, which were taken for household consumption. The potential of this variety was explored further in the phase 2 trials.

5.5.7 Fishing gear efficiency and ownership characteristics

Earlier situation analysis indicated that net ownership influenced CF participation and yield distribution (section 5.5.8). Access patterns and CPUE levels associated with different fishing gears were therefore assessed in order to explore such relationships. A total of 94 gears in four categories were used in GUR, IMK and SER tanks on successive days (Figure 5.4). These were employed by 80 groups of fishermen consisting of 1-7 individuals with a mean of 2.3, 2.5 and 2.1 persons per group in GUR, IMK and SER respectively.

Various sized multi-twine nylon gill nets ranging from 3.2 cm to 8.9 cm (stretched mesh size) constituted 87% of the total numbers of gears due to their robustness and efficiency under CF conditions. 'Trammel' nets consist of a sandwich of 3 different sized gill nets, typically mono-filament. Although they can be highly efficient they are costly, require greater effort to deploy and are susceptible to fouling and damage in seasonal tanks. They are therefore used relatively infrequently. The remaining gears were individually operated cast nets and wicker hand traps (*karaka*). These gears were most efficient in very shallow water (i.e. < 1m max depth). Consequently, they were therefore most prevalent (43% of the total) along with smaller mesh gill nets in SER where greatest individual effort also took place.

Monitoring capacity during CF events was sufficient only for measurement of mesh sizes but not overall net dimensions although both have consequences for CPUE. Nets with larger mesh sizes are also manufactured in larger dimensions (i.e. '13cm' nets are typically around 30m x 2m while '3.2 cm' nets are rarely more than 10m x 1m). Whilst many owners will sub-divide their nets for different environmental applications or as they become damaged, most of the largest and costliest nets in operation (>7cm) were borrowed from external semi-professional fishermen of perennial tanks (for which purpose they are maintained intact). Although few in number these same nets proved most efficient in terms of CPUE and returns to owners / users during the first day of CF, as they selectively removed the larger, more valuable tilapia (mean 251g, STD 47g: Figure 5.3). For 8.9cm nets in GUR (utilised by 2.3% of all participants), CPUE rose to a maximum of 2.4 kg participant^{-1} hr^{-1}.

In GUR and IMK, a second lower peak in CPUE (0.9-0.4 kg participant^{-1} hr^{-1}) was associated with two smaller mesh sizes; 3.8cm and 5.1cm. These gears yielded tilapia of mean weight 43g (STD 7g) and 114g (STD 13g) respectively. Over 48% of all gears, operated by exactly 50% of the total participant number consisted of these sizes. Small and intermediate sized gill nets (5.1cm – 7.7cm), but not larger nets were selective for snakehead (mean weight 408g, STD 105g), resulting in consistent returns (CPUE 0.23-0.5 kg participant^{-1} hr^{-1}) to each of these sizes in IMK where snakehead were abundant. Snakehead over a wide range of sizes, were particularly susceptible to becoming entangled in trammel nets, making this the most efficient gear in IMK; snakehead contributed 1 kg to the overall CPUE of 1.35 kg participant^{-1} hr^{-1}.

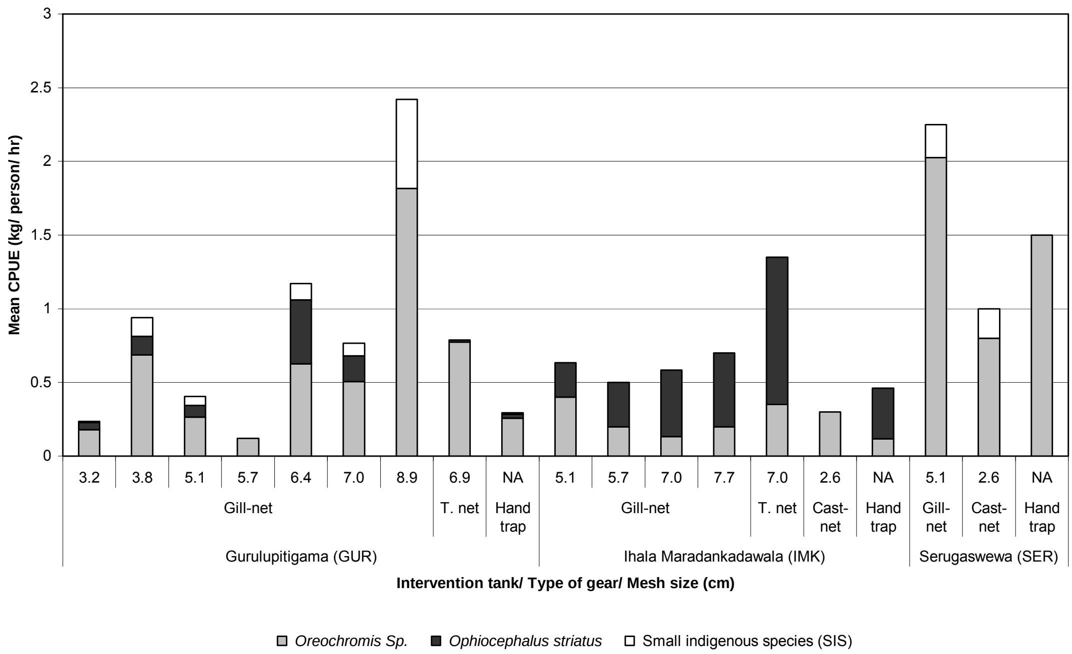


Figure 5.3 Mean CPUE for different types of gear and mesh sizes deployed during collective fishing events in GUR, SER and IMK tanks, Jul - Aug 2000

CPUE differences were much less marked between gears in SER, though gill nets still proved most efficient, in part because they were much less size selective due to the 'drag-net' operation described above. Most tilapia harvested from this tank ranged between 40-120g, i.e. significantly smaller than the mean size harvested from the two larger tanks.

Net ownership cross-referenced against wealth ranking results (Figure 5.4), indicated local ownership broadly in proportion with the participation levels described below, i.e. a negligible quantity of gears were owned by better-off families, while 39% and 60% of the total number deployed were owned by medium wealth and poorer families respectively. This placed poorer families in particularly strong position in terms of informal access rights, i.e. these groups already possessed the means to exploit the resource prior to stocking.

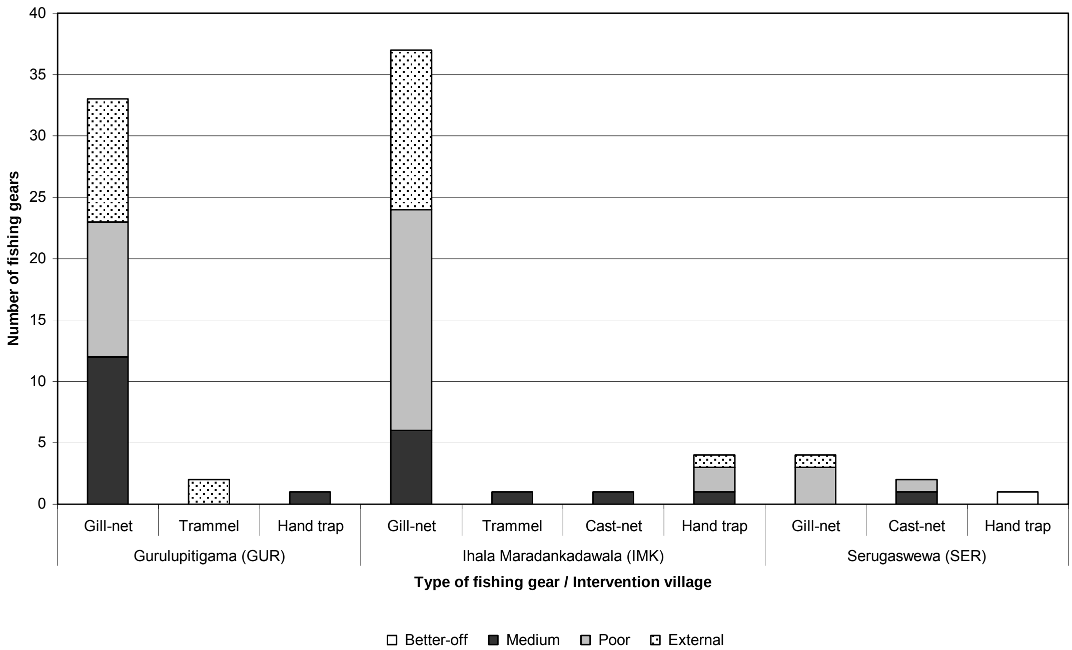


Figure 5.4 Ownership of fishing gears used in phase 1 collective fishing by wealth rank and domicile

The level of return going to the net owner is subject to several inter-related factors such as the nature of informal relational ties, the type and size / length of gear, the number of fishers deploying the gear and the size of the harvest. In most cases owners received a fixed share calculated according to the value of the gear and size of the team, i.e. a share equal to that received by each of the participants 'went to the net' in the case of smaller gears, while a more favourable fixed proportion of the catch (i.e. 25%), went to the owners of larger, costlier gears. In others instances gears were provided on a reciprocal loan basis, while the gifting of a small amount of fish was typically sufficient recompense in the case of intra-family loans. In most cases owners received only 1-3 kg of fish net^{-1} day^{-1}, which was consistent with the relatively low yields described above. These sharing mechanisms meant that gears were therefore available at reasonable terms and sufficient quantity.

External gears, either loaned or deployed by external participants, constituted 33% of the totals in both GUR and IMK and 14% in SER, while external participants contributed 13%, 29% and 12% of the total fishing effort in the same tanks. These results are consistent with earlier findings indicating that villagers increase informal cooperation with ‘outsiders’, in order to access sufficient gears to efficiently harvest larger seasonal tanks, where sufficient CPUE potential is demonstrated. However, while a comparable number of external gears were deployed in IMK and GUR, a greater proportion of the harvest was retained in GUR (Figure 5.6). This was due to the organised exclusion of external participation at the start of the harvest when the most productive fishing takes occurs (Figure 5.5 and Table 5.5), i.e. 82.3% and 69.8% of total yields from GUR^t and IMK^t respectively, were retained by the local community. Some 85.7% of the yield was retained from SER, though in this case the relatively low overall yield, smaller fish size, the short duration and impromptu nature of the event served to both exclude and make outside participation less attractive.

5.5.8 Collective fishing participation and yield distribution

A total of 225 ‘man-days of fishing effort were recorded over the course of six days collective fishing in GUR, IMK^t and SER (Table 5.7 and Figure 5.5). Discounting repeat fishing, i.e. by individuals fishing on more than day or in more than one tank, and multiple participation by members of a single household, 121 households were represented by participants from within the respective local communities and 33 from households in neighbouring communities. This resulted in direct benefit going to 51 (53%) and 52 (45%) of all households in GUR and IMK respectively. In IMK village, 39% and 10% of households participated in IMK^t and SER respectively.

As indicated above the highest returns went to those fishing on the first day, with larger nets (in IMK and GUR) and those fishing on multiple days. In GUR 13% of households fished more than once, while in IMK 9% of households fished more than once, or in both tanks. The residual depth of GUR also meant that many younger participants could only fish effectively in littoral areas where yields were lower.

Table 5.7 Numbers of households receiving benefits from collective fishing in three village tanks

Village	GUR	IMK	
No households in village	119	128	
Collective fishing (CF) tank	GUR[t]	IMK[t]	SER
No CF days	3	2	1
Total fishing by local participants (man days)	83	83	13
Total fishing by external participants (man days)	11	33	2
Multiple fishing – local participants[1]	20	27	11
Multiple external fishing – external participants[1]	3	10	0
No households represented by local participants	63	56	13
No households represented by external participants	8	23	2
Formal distribution among non-participant households	17	0	0
Total households receiving direct benefit	80	58[2]	13
% Village households receiving direct benefit	67.2	43.8	(10.2)

[1]Discount value derived from: (1) participation by multiple household members (2) repeat fishing on multiple days (3) repeat fishing in multiple tanks
[2]Inclusive of 2 of 13 households who fished in SER but not IMK

In GUR, greater equity was achieved through formal redistribution of part of the first days catch by FO officials. This amounted to approximately 1.5kg going to each of 17 households, including a small number of female headed households (who had previously participated in the ‘salvenia *Shramadana*’ but were not represented at the collective fishing). Originally the plan had been to levy a charge of ¼ of the total catch of each group for this purpose, but in the event this was progressively adapted to the size of individual yield and willingness to contribute. Of 17 fishing groups, 12 with higher yields contributed up to ¼ of their total yields accumulating a total of 26.5kg. Only two youth groups with catches above 4kg per person, declined to contribute. This raised the number of direct beneficiaries in GUR to 80, or 67% of all households (Table 5.7).

In addition to this formal redistribution, slightly over 50% of participants in both GUR and IMK reported that they intended to share part of the catch with neighbouring relatives, while larger surpluses would be dried for later household consumption. Only in GUR were any commercial transactions observed; 2kg of snakehead was retailed to a passer-by (Rs 70/kg), while several external net owners, observing from the bund, also intended to sell their share of the catch. Two bicycle-vendors looking for snakehead were also in attendance but could find no one interested in selling fish at wholesale prices (Rs 40-50/kg).

Overall, 76% of local participants were successfully cross-tabulated with wealth ranking data (Figure 5.5). This information was then used to asses the distribution of catches amongst different wealth groups (Figure 5.6). This analysis considered only direct participation, i.e. no systematic information was collected regarding the wealth status of households to which yields were formally or informally re-distributed as described above.

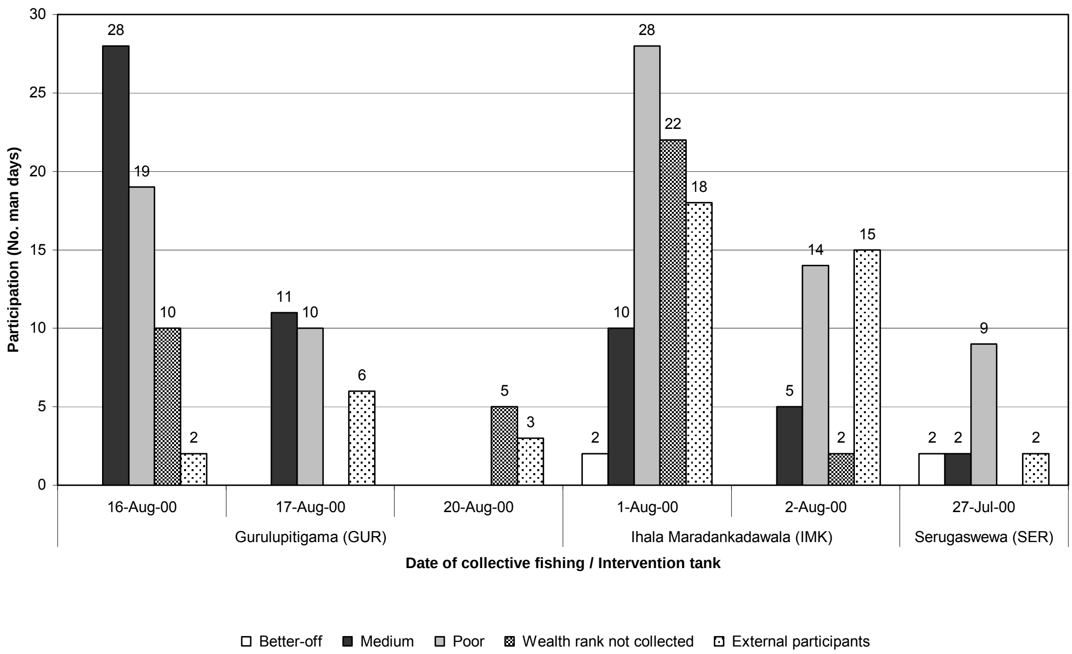


Figure 5.5 Individual participation in phase 1 collective fishing, by wealth rank and domicile (data values shown)

Participation in every CF event was almost entirely restricted to individuals from poor and medium wealth-ranked households. The proportion of poor participant man days was highest in IMK; 73% of ranked households compared to 43% in GUR. This was possibly due to the greater influence of taboos on fishing associated with the higher-caste status of the village.

Yield returns to different wealth groups exhibit a similar trend, with 76.3% of locally retained yield in IMK and 35.8% in GUR going to poor households and most or all of the balance to medium wealth households, again considering only successfully cross-tabulated individuals; Figure 5.6.

Though not possible in this survey, in the phase 2 trials, the selection of research sites in adjacent watersheds, also meant it would be possible to gain some insight into the wealth status of external fishermen through their reciprocal participation in each others CF events (section 5.6.4).

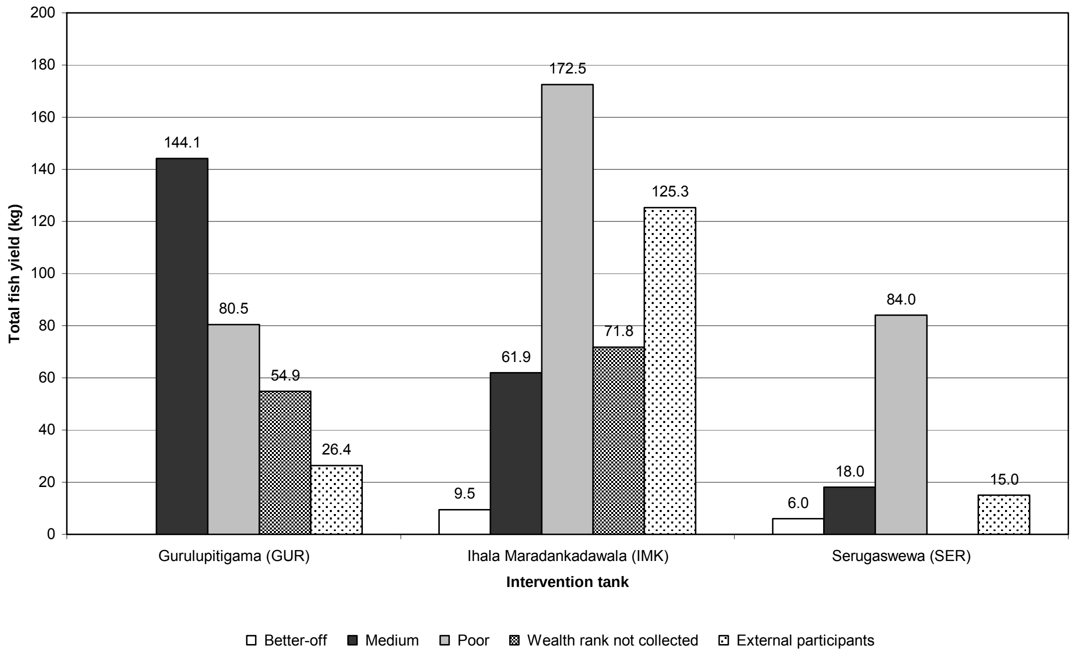


Figure 5.6 Distribution of collective fishing yield amongst different wealth groups and external participants

5.5.9 Collective management outcomes and fishing conflicts

Ostrom (1991) and Uphoff (1998) characterise four internal variables which, assuming rational behaviour, influence individual decision-making: (1) expected costs (2) expected benefits (3) internal norms, attitudes and beliefs, i.e. influenced by broader meanings and symbols within local culture whereby individuals place value on actions in and of themselves, often over and above economic outcome (4) discount rates, i.e. the extent to which individuals defer immediate gain in order to receive greater future benefit. As individual knowledge of cost-benefit ratios are far from clear in these complex risk-prone production situations, normative values, i.e. social taboos, caste differences and relational ties take on particular significance in decision-making. These shared values also increase the ability of individuals to predict the actions of others in otherwise uncertain situations, thereby increasing trust and reciprocity and the likelihood of mutually beneficial collective action. In the current example, the decision by all villages to focus on collective fishing was strongly influenced by such conditions.

Focus on interaction amongst users, i.e. a political ecology perspective (Chapter 1), is appropriate for at least two reasons. Firstly it views resource sustainability in the light of institutional sustainability and secondly it moves from an artificial sectoral to a systemic view of resource appropriation. This political ecology perspective is of particular relevance to the two larger water bodies; GUR^t and IMK^t, where the number and size of different interest groups are larger and interactions more complex.

In practice specific resource-use interest groups were embedded in broader underlying social (i.e. generational) and political affiliations. Political divisions in turn point to the influence of both local and external decision-makers on resource use outcomes. Ostrom (1994) characterise three levels of decision-making corresponding with the interaction hierarchy suggested above (1) the operational level corresponding with individual choices (2) the collective choice level corresponding with local interest groups including resource users (3) the constitutional level corresponding with external decision making.

Unfortunately despite the articulation of 'participatory objectives', very often people's organisations constituted by external agencies to implement higher level interaction rapidly become 'contractors'; the last link in a development delivery chain. To achieve sustainable impact, requires instead that appropriate institutions develop their own vision and mission strong enough to promote at least five other essential features simultaneously required for an institution to survive and grow: organisational and financial accountability, collective learning, financial management and linkages with other community and external organisations (Fernandez 2000).

Our small research team possessed insufficient experience in institutional capacity building, conflict mitigation, advocacy or other requisite specialisations to attempt to effect such positive change. Therefore the pre-existing social structure of IMK and GUR (section 4.3.3) effectively predisposed two very different intervention outcomes in terms of mutually beneficial collective action.

In GUR strong and charismatic leaders brokered pragmatic consensual outcomes based on compromise and sanctionable enforcement. Despite a similar number and attendance at interim meetings held to plan CF events with local government support, no comparable consensus was achieved in IMK. Ultimately this resulted in unilateral action by a specific interest group leading to unrestricted 'mass fishing'. In both villages there were those who prioritised bathing and wished to curtail even collective fishing during the dry season. This lobby was most vociferous in IMK, as they feared it would be impossible to regulate collective fishing once it had commenced. Conversely others argued that to delay CF would risk further escalation in poaching, leading to persistent water quality deterioration and inequitable yield distribution.

In IMK, the final meeting prior to CF, attended by over 50% of village households, became extremely confrontational. Immediately prior to the meeting, several villagers had gears confiscated by the GN for engaging in unsanctioned night fishing. This group of around 15 persons attended the meeting in a drunken belligerent state and finally walked out declaring that owing to the indecision they would themselves initiate CF the following day. On the same night some members of this group invited participation of external semi-professional fishermen who brought replacement gears. Attempts to curtail this activity resulted in hospitalisation of one villager. Meanwhile, word of the intended CF had rapidly spread and a large number of participants from four neighbouring villages arrived to join in unrestricted fishing-activity early next morning. Many other external participants were unrecognised by local villagers. Numbers increased as the morning progressed, many participants consumed alcohol openly and at one point a second confrontation related to the previous night's incident broke out.

Underlying this inability to achieve consensus were unusually entrenched political divisions predicated on patronage which had contributed to discontent and distrust within the village. Perhaps due in part to its low-caste status villagers in GUR were more unified in resisting such external pressures for their common good. The GUR FO president gave a related example of their stronger institutional capacity; by strategically ensuring representation of supporters of both main political parties in executive positions, the village avoided the extreme oscillation in service / welfare provision, and associated factional conflicts that dogged more polarised communities such as IMK.

Although IMK village officials brokered an informal agreement to terminate fishing after the first day of CF, substantial numbers resumed fishing the following afternoon. Detailed monitoring of this activity by research staff had an unforeseen effect. Some of those involved cited their cooperation in research activity as a justification for their continued activity. Consequently, direct observation was terminated after the second day. Thereafter, collective (or 'mass') fishing continued for several days, though at much reduced levels.

Similar unregulated activity occurred on the third day of CF in GUR. However, this was tolerated without real conflict, as the numbers involved were considerably lower (Figure 5.5) and their activity confined to remoter areas far from bathing points. The greatest potential for conflict in GUR came about as a result discontent amongst a number of external participants, some of them with family relations in GUR, who expected to participate as they had in previous years. A compromise was finally reached after careful negotiations with DDS and FO officials, whereby they would be allowed to fish late on the first day, after most local effort was complete, and on successive days. In this way they defused a tense stand-off whilst also maintaining reciprocal access rights to CF to neighbouring tanks.

5.5.10 Phase 1 summary and discussion

In terms of the broader research goals intervention outcomes must be evaluated according to two key criteria. Firstly, equity; did the outcomes adequately address the needs of poorer as well as better-off sections of the community? Secondly, sustainability; what is the likelihood of communities repeating or further adapting the enhancement strategies. The answer to both questions lies with net impacts on livelihood outcomes as perceived by different stakeholder groups. The initial research hypotheses (RH) are reviewed below according to these criteria and modified hypotheses, the basis for the design of phase 2 interventions, are presented in section 5.6.

The trials in ULP clearly failed for technical reasons. Nevertheless, a valuable lesson was learned regarding the adverse short-term effects of de-silting on aquatic production; a negative effect which has not been quantified before. The fact that de-silting is a common intervention makes the finding especially significant.

Most of the CF harvests in the other communities contributed directly to household welfare in two ways (1) income substitution and (2) improved food security, i.e. most respondents purchased less commercial product during and after CF, but also consumed more fish than they otherwise would have, at this lean period in the agricultural calendar (Appendix 27). Furthermore, direct and indirect benefits accrued to a large proportion of poor and medium wealth households in both IMK and GUR. In other words there were human and financial capital gains to a majority of households. This was a consequence of accessibility to low cost gill nets by the same groups while better-off families continued to rely on commercial production. Social cohesion improved only where there was successful coordination of institutional effort as discussed below.

Key to sustained adoption is the perceived cost / benefit ratio to individual stakeholders and the wider community. Yield returns were clearly one of the most readily enumerated benefit measures, the extent of which was fairly accurately perceived by different stakeholders due to the brief and intensive nature of CF events. Although there were many beneficiaries, individual returns were relatively low. More seriously, there was no significant increase above pre-intervention levels in the two largest tanks. Although there were mitigating environmental factors, these outcomes still fell below many participants expectations.

The SER intervention can be adjudged as the most successful in terms of area / yield returns, individual CPUE and overall economic profitability. This was due to low residual storage levels which permitted complete rather than partial harvest such as those in IMK^t and GUR^t. Conversely the number of SER beneficiaries was relatively low.

Other than for fishing gears, participants bore no direct financial costs as seed was provided free of charge. As sustained adoption would be contingent on farmers meeting both these costs, a simple cost-benefit analysis is presented in Table 5.5. Total yields, excluding the proportion of the yield which went to external participants (i.e. incorporating the cost of gear rentals) are priced at the prevailing retail cost of table-sized tilapia for which tank production was substituted. No allowance is made for depreciation of locally owned gears, discounted interest / inflation rates or labour costs. Neither was any estimate possible for the increase in snakehead yield which potentially arose through elevated tilapia predation, or recreational benefits which undoubtedly also provide a strong incentive to participate.

Only in SER did this analysis indicate significant profit (69%). This was possible in a relatively short grow-out period of only six months. Poor recovery / survival in GUR^t resulted in a break-even situation. In IMK, additional yield losses to unrestricted external participation resulted in a substantial financial loss (-44%). Furthermore, the proportion of the tilapia harvest that could be attributed to stocking in GUR and IMK was undetermined. Therefore only in the smallest tank might there have been sufficient incentive to re-stock with cultured seed. Set against this was the small mean size of fish from SER, which have low consumer preference and commercial value (Murray 2004b).

These markedly different outcomes indicate that because of CPUE effects associated with residual water-spreads, higher stocking densities are required to yield profitable CF returns in larger tanks. For reasons of limited seed availability and cost, together with the many other uncertainties associated with yield outcomes (Chapter 1), such investment is unlikely.

Fishing required trade-offs with other water uses, notably loss of bathing amenity for several days or more during the dry season. However where tanks already contained permanent standing stocks, this problem was no more severe than in previous years. More serious were conflicts arising when no consensus could be reached regarding CF strategy. For this and other reasons (i.e. re-stocking) the existence of effectual community-based organisations was a pre-requisite for mutually beneficial collective action. Consequently, in IMK, stocking interventions only resulted in further erosion of already weak social cohesion and there was little likelihood of any future repetition of the intervention.

Conversely strong institutional capacity and social cohesion in GUR both predisposed and was further strengthened through organised collective fishing, *Shramadana* events and formal yield redistribution to those unable or ineligible to participate, such as female headed households. Effective management also resulted in retention of a larger percentage of the catch within the village without significantly compromising reciprocal rights to collective fishing in other tanks.

Such organisation was not with out cost however. Considerable effort was required on the part of a small number of village leaders, who received no additional tangible benefit, for their inputs. Furthermore, no surplus was available to raise funds for additional village development works as had been originally envisaged. Such funds could also have contributed to the financial independence and sustainability of village institutions. Therefore in GUR too, it was doubtful whether sufficient incentive existed to promote future collective action.

Lack of production surpluses also meant there was little possibility for any commercial post-harvest production strategy (RH A2.1), though most participants dried a proportion of their catch for future household consumption (RH A2.2).

Several of the preliminary hypothesis (RH A1.1 – A1.3) relating to demarcation of fingerling and broodstock production in tanks of different size and seasonality (Appendix 30), proved unfeasible as the yield levels returned indicated little or no potential for commercial seed transactions between neighbouring communities. Nevertheless, where a range of tank classes are incorporated in a single *purana* complex, there remains a potential for internal transfers, i.e. requiring no commercial transaction. For example many of the smallest tilapia from SER which had little consumption value might have been usefully restocked in the IMK^{t} and / or broodstock moved back after the rains.

An alternate method of promoting inter-community linkages based on the *Shramadana* experience in GUR was also explored (RH A1.4). Villagers in neighbouring MDW (a relatively affluent high-caste *Goyigama* village) were asked whether they would permit GUR villagers to participate in an organised CF event in return for clearing aquatic weeds from their 'base' axial village tank, which was as heavily occluded as GUR^{t}. Although very few MDW villagers participated in any fishing activity, the idea of a formal arrangement was universally rejected. Further investigation revealed that the caste polarisation between the two villages (section 4.3.3) was the main reason for this.

In IMK too, despite the open access conditions prevailing at CF, only a very small number of low-caste villagers from neighbouring Maduragama (MAD) participated, though this community included a large number of regular subsistence fishermen. Caste differences therefore also appear to represent a considerable barrier to integrated enhancement steps being taken at the watershed level.

A final conclusion relates to the question of fishing gear provision as an intervention component? Some respondents cited lack of sufficient gill nets as a constraint to efficient collective-harvesting in IMK^t and GUR^t. Additional gears may indeed have increased individual CPUE in these larger tanks; however results demonstrated that where yields from test fishing, or poaching, surpassed a threshold CPUE level external gears were rapidly mobilised with both positive and negative repercussions as discussed above. Gear provision may conceivably have provided an alternative means of regulating external participation in IMK. However without consensus such action would probably have exacerbated the existing conflict as different parties in the conflict, including better-off non-participants, would seek to control them. Obviously the answer to this question will depend upon site-specific considerations, but no clear justification existed in the current examples where such provision simply risked promoting further dependency.

5.6 Phase 2 Stocking interventions

The primary research hypotheses outlined in section 5.4 were re-formulated as follows in light of the phase 1 outcomes described above:

1. Site selection

- B1.1 Could more demonstrable impact and increased likelihood of sustainable adoption be achieved by stocking smaller seasonal village tanks (radial – axial 1), in which resident fish stocks are periodically eliminated?
- B1.2 Could the stocking of such tanks also target marginal low-caste communities who are most dependent on subsistence production?

2. Stocking strategy

- B2.1 Could the use of locally sourced seeds in a low input / output enhancement strategy increase the likelihood of sustainable adoption?

- B2.2 Could the stocking of predators such as snakehead juveniles improve net benefits by minimising tilapia stunting while producing a valuable by-catch?

3. Harvesting strategy

- B3.1 Could promotion of staggered harvesting strategies combined with strategic fishing gear restrictions mitigate potential conflicts with other water users, while ensuring greater retention of fish and beneficial impacts for the immediate community?
- B3.2 Could staggered harvesting strategies sustain greater yields, higher market prices and hence increase profitability?
- B3.3 Could staggered harvesting strategies bring direct benefits to poorer consumers through increased production of smaller, more affordable fish through much of the year?

4. Collective action

- B8. Could the implementation of a more participatory adaptive group-learning approach, improve institutional capacity and potential for mutually beneficial collective action?
- B9. Would it be possible to implement levies on culture-based fisheries to fund maintenance of neglected tanks or for development of other village institutional / physical infrastructure, and, could this strengthen social cohesion by enrolling the whole community as stakeholders in the fishery?

5.6.1 Phase 2 site selection

Because of the promising technical success demonstrated in SER, our focus for phase 2 trials shifted to smaller radial and axial 1 tanks ranging from 1.9 – 13.1ha at MWS. However rather than the satellite tanks of larger *purana* complexes, attention shifted to smaller PCs, where such tanks were likely to be the principle ‘base tank’ of the community (Table 5.8). This also had the following implications:

- Attention would now focus on the most marginal and mainly low-caste communities, often excluded from conventional stocking interventions.
- Collective decision making would be simplified as a result of the lower number of people involved (i.e. 25-51 households per village). Conversely trade-offs required between multiple water uses might be more intense due to the greater seasonality of these water-bodies.

- External participation in these small tank fisheries would also be likely to be very low, further simplifying management strategies.

SER was also re-stocked in the phase 2 trials so that the technical potential of hatchery reared tilapias could be compared with wild sourcing, though no impact monitoring other than production outcomes would take place on this occasion. A further attempt would also be made to negotiate access to low-caste villagers from neighbouring MAD who placed greater value on subsistence fishing (Chapter 4).

Eight villages (Chapter 4: Figure 4.2), fitting most or all of the above characteristics were identified from the 24 *purana* complexes characterised in the watershed level key informant surveys (Chapter 2). Meetings were held in each village to propose and discuss project interventions. In each case these forums were incorporated into existing DDS meetings in order to canvas the broadest range of opinion.

In Ihala Diulwewa, a village of low-caste potters in the Anamaduwa area, an unsuccessful attempt was made to engage a youth group after promising early liaison. This group was heavily involved in informal fishing activity in a wide radius around the village (Murray and Little 2000b). It was postulated that giving the group responsibility for managing their own tanks could reduce their reliance on external resources and associated conflicts. Youth were already organised into an active 'sports' society formulated under the auspices of the government welfare department. Unfortunately although one of the village tanks had recently been rehabilitated at government expense, it proved impossible to negotiate access for the purpose.

In DDW (*goyigama* farming caste) where good technical potential was identified villagers resisted the idea of stocking, fearing escalation of regular internal multiple-use conflicts (Chapter 2) over unregulated fishing access, would outweigh any benefit. The same fear was raised in LHG, where village leaders felt that poorer youth in the village were beyond the control of any village institution. The suggestion was then put forward that these same 'anti-social' groups might be co-opted into the institutional life of the village by giving them the responsibility of forming a fishing society. While the suggestion was declined in DDW, participants in LHG including a number of youth agreed to the idea. Positive responses were also obtained in two other low-caste villages; Galenbindunewewa (GBW) and MAD (Table 5.8). In the latter village two adjacent tanks were selected for stocking. Consequently, each of the five tanks finally selected for this phase were located in the Giribawa area.

In terms of tank size and seasonality characteristics this selection fell into two broad groups; three smaller highly seasonal tanks; Karambewewa (KBW), Lunawewa (LUN) and Serugaswewa (SER: 1.9ha – 3.8ha) and two larger semi-seasonal tanks; GBW^t and LHG^t (8.4ha and 13.6ha respectively). As noted in Chapter 4, GUR village was also incorporated in the phase 2 longitudinal monitoring regime, on this occasion as a low-caste, non-intervention control site.

5.6.2 Baseline survey of phase 2 tank production characteristics

Results of a baseline survey similar to that undertaken in phase 1 are summarised in Table 5.8. Only one tank, GBW retained sufficient residual water storage over the previous dry season to carry over significant numbers (and variety) of fish stocks. In KBW, a small number of juveniles persisted in a concrete bathing-well, constructed in the draw down area, after the rest of the tank had dried (Appendix 22; Plate A22.1).

In addition to these carry over potentials, spill events that occurred during the month of April following stocking, also provided some potential for natural recruitment (Chapter 2: Figure 2.22). Only in GBW^t, LHG^t and SER were flows of substantial and long enough duration, to warrant a limited amount of spill-fishing activity by local villagers. This was undoubtedly the source of a quantity of snakehead and other local varieties subsequently harvested from SER. Sweep netting indicated small numbers of juvenile tilapia attempting to move up from KBW to LUN though low flow rates resulted in these fish become trapped below the LUN surplus weir. This combination of standing stock and interim spill characteristics meant yield outcomes for the principle stocked species in LUN and KBW could be attributed entirely to stocking interventions, and for the most part in LHG^t and SER. With its significant standing stocks, the situation in GBW^t would be subject more to comparison with yields in previous years.

Other than partial excavation of bund areas in the two larger tanks, no significant de-silting activity had been carried in any of these tanks over recent years. Therefore, this was removed as a background variable in this trial phase.

Table 5.8 Baseline production characteristics of phase 2 intervention tanks in Giribawa research area.

Village name[1]	MAD		IMK	GBW	LHG
Caste	**Gypsy**		**Farmer**	**Dhobi**	**Black-smith**
Tank name[2]	**KBW**	**LUN**	**SER**	**GBW[t]**	**LHG[t]**
No households	51		21	25	47
Spatial class	Axial 1	Radial	Radial	Axial 1	Axial 1
i. Surface area at FSL (ha)	1.9	3.8	3.2	8.4	13.6
ii. Surface area at 50% MWS (ha)	0.9	1.9	1.6	4.2	6.8
iii. Surface area at 50% LS depth (ha)	0.8	1.6	1.3	3.1	3.2
iv. Surface area at DSL (ha)	0.15	0.29	0.32	1.06	3.57
Irrigation *yala* 00	N	N	Y	N	N
Irrigation *maha* 00	Y	N	Y	N	N
Irrigation *yala* 01	Y	Y	Y	Y	Y
Year of last rehabilitation activity	1997	1987	1995	1996	1997
Type of rehabilitation activity[3]	HW	HW	HW	HW, PD	PD
Last year tank completely dried	2000	2000	1999	NA	2000
Reason for drying	Low rainfall	Low rainfall	Lift irrigation	NA	Low rainfall
Drying frequency over last 5 yrs	5	5	2	0	3
Spill frequency over last 5 yrs	2	2	5	3	3
Last year of spill linkage[4]	1998	1998	1999	1998	1998
Surplus weir migration potential?	High	High	High	Medium	Medium
Last year of collective fishing	1997	1997	2000	2000	2000
Species indicated by test fishing Nov 00[4]	M,C,L	none	none	S,T,M,C, P	none

[1&2] GIR = Giribawa KBW = Karambawewa, LUN = Lunawewa, GBW = Galenbindunewewa, LHG = Lokahettiyagama, MAD = Maduragama

[3] HW = Head-works (repairs to bund, sluice and / or surplus weir), PD = Partial de-silting, CD = Complete de-silting.

[4] All tanks also had low levels spills during April / March 01

[5] T = *Oreochromis Sp.*, S = *Channa striatus*, P = *Puntius* spp, C = *Anabas testudineus*, M = *Mystus* Sp. L = *Lepidocephalichthys thermalis* (common loach)

5.6.3 Phase 2 stocking strategies

Lack of marked improvement in yield outcomes in phase 1, and difficulties procuring hatchery reared tilapia stocks, prompted the adoption of a different strategy in the second phase. These trials would rely exclusively on a range of varieties and life stages of wild-sourced seed from neighbouring perennial tanks in lower-watershed locations (Figure 5.8). Tilapias were once again the primary culture species though this time they would be wild *O. mossambicus* / *O. niloticus* hybrids. Tanks that had dried prior to stocking would be simultaneously stocked with juvenile snakehead of suitable size, to control populations of free-breeding tilapias. Smaller numbers of larger tilapia 'broodstocks' were also stocked in each instance, in order to accelerate self-recruitment.

Tilapias were obtained from two locations using three different capture methods: (1) fry were harvested in recently inundated grassy littoral areas around Rajangane Reservoir using fine mesh hand nets (Plates 5.5 A and B), (2) larger juvenile and adult fish were caught using a cast-net deployed from the bund of Pahala Giribawa Wewa (PGB). This a large perennial tank (89ha) located at the base of the MAD and LHG micro-watersheds (Figure 5.1), (3) local commercial fishermen were also recruited to capture larger specimens from Rajangane using 5cm gill nets. Journey times between the various recipient and donor sites varied from 20 minutes to 1.5 hours. In each case fish were transported by van, in open, half-filled plastic forty-five gallon drums (Plate 5.6). Transport stocking densities varied widely between 15-140 g/l, with the lowest densities for fry. Transport temperatures varied between 27-30.5°C and temperatures at receiving sites between 27.5-32°C. While it was possible to hand count larger fish, in order to minimise stress, fry numbers were estimated using a crude volumetric displacement method i.e. based on the water displacement of a counted sample of fry.

A B

Plates 5.5 A and B: Members of GBW fishing society hand-netting tilapia fry in recently inundated grassy littoral areas of Rajangane Reservoir, Dec 2000 (happa used to hold adult tilapia is visible in the background of Plate B).

Plate 5.6 Members of GBW fishing society stocking tilapia fry and adults from Rajangane Reservoir in their village tank (Dec 2000)

The first two methods were undertaken by villagers from participant villages with support of project staff. Catches were transported directly to trial tanks where they were released in littoral areas with the assistance of other participating villagers. ‘Brush parks’ were constructed at release sites to create additional shelter for fry.

Commercial fishermen were requested to store their catches in make-shift happas, constructed from mosquito netting (supplied for the purpose; Plates 5.4B) which were then collected within 24 hrs of capture. This method proved the most costly and unpredictable in terms of survival rates, which averaged 69% (STD 21%). Mortalities including any moribund fish were rejected prior to transport. Post transport mortalities averaged 5% (STD 3.6%). Negligible mortality was associated with cast-netting of local tanks (PGB), for which transport times were also shortest. Survival of more delicate fry collected from Rajangane averaged 76% (STD 17%) with combined collection and journey times to the different intervention tanks ranging from 1hr 45mins to just over 3hrs.

Project assistance at this stage took two forms (1) the Rajangane fishermen were paid the prevailing commercial wholesale rate (Rs 30/kg) for their catch of live fish (2) locally fabricated hand nets / happas and transport facilities were provided free of cost. The future import costs, which villagers might have to face were they to repeat the exercise, amounted to an average of Rs 3,200 per tank. This consisted of a total of Rs 1,400 for live fish, Rs 2,600 for gears while transport costs were most significant with van rental amounting to Rs 12,000 over twelve days (i.e. 2-3 transports per tank).

Clearly local capture (i.e. from PGB), would involve considerably less cost and effort. However one clear advantage was associated with procurement from Rajangane. Despite a paucity of local rainfall, substantial inundation had taken place in this major reservoir, as it is a system tank receiving diversions from the wetter hill country. This stimulated a peak in breeding activity, reflected in high densities of fry in littoral areas and the condition of adult fish. Consequently, CPUE for fry was extremely high; a single individual was regularly able to net up to 6,000 fry within a period of 1 - 1.5hrs. Greater fishing efficiency was achieved when fishers worked in pairs sweeping towards each other. Conversely, CPUE for smaller juvenile fish (20-50g) was much higher in PGB, due to relatively low and falling water levels, at the same time as levels in Rajangane were rising.

This hydraulic variability presented a great opportunity for advanced stocking in the seasonal tanks and it is recommended that tilapia fry should be sourced in a similar manner where such opportunity presents itself. Conversely, tilapia broodstocks which require greater investment in transport should be preferentially sourced from nearby large-perennial tanks in the lower-watershed (>60-70ha, i.e. in which rights to fish are likely to be less restricted than in smaller tanks).

Snakehead fingerlings were stocked in three tanks; KBW, LUN and LHG[t] between January and February 2001, after all the other introductions described above were complete. Locals were very familiar with their ecology, referring to the highly visible, colourful shoals of juvenile fish as *petav pola* (*petav* litteraly means young, but the phrase translates as ‘baby fish markets’ - Plates 5.8 A and B) and children were regularly observed collecting them. Local villagers, observed by project staff, caught the fish amongst emergent vegetation in the littoral areas of two larger axial tanks (including PGW), using hands nets and other simple improvised gears. They were then transported in buckets by foot. Most of the limited numbers of snakehead fingerlings captured in this way were stocked in the two of the smallest tanks: KBW and LUN. It proved more difficult to elicit similar effort in LHG where only a handful of fingerlings were stocked.

Whereas snakehead fry could be harvested selectively because of their discrete shoaling behaviour, the tilapia-fry harvest method described above resulted in the capture of a small percentage of indigenous fish species (5-10% of the total number) which share the same littoral nursing grounds as tilapia. These consisted predominantly of various minor cyprinids along with a small number of catfish (*Mystus* spp.). Subsequent harvest in MAD also indicated the presence of common carp juveniles (section 6.2.10). Cast netting in PGW also resulted in the capture of snakeskin gouramy (*T. pectoralis*), which occurred in mixed shoals with adult tilapia. These were pooled and stocked in one of the tanks, GBW^t (Table 5.9). The method therefore has potential to extend the range of less resilient species which rarely migrate naturally to more seasonal tanks.

Table 5.9 Summary of phase 2 stocking activity in the Giribawa research area, 2000/2001

Village name	MAD		IMK	GBW	LHG
Tank name	**KBW**	**LUN**	**SER**	**GBW^t**	**LHG^t**
Date stocking commenced	18 Dec 00	2 Dec 00	10 Dec 00	28 Nov 00	11 Dec 00
Date stocking completed[1]	24 Jan 01	8 Feb 00	15 Dec 00	14 Dec 00	8 Feb 01
1. Tilapia broodstock					
Total stocked	40	245	59	254	81
Stocking density (fish/ha 50% MWS)	42	129	18	60	8
Weight range (g)	25-90	30-500	20-86	38 - 500	20-90
Weighted mean (g)	55	75	55	88	51
2. Gouramy broodstock					
Total stocked				33	
Stocking density (fish/ha 50% MWS)				4	
Weight range (g)				20-50	
3. Snakehead fingerlings					
Total stocked	500	1000			20
Stocking density (fish/ha 50% MWS)	529	527			3
Length range (cm)	1.5-2.5	1.5-2.5			4-6
4. Tilapia and other wild fry[2]					
Total stocked	5,000	21,000	13,000	21,000	21,000
Stocking density (fish/ha 50% MWS)	5,285	11,075	8,012	4,987	3,097
Total SD (fish/ha 50% MWS)	5,540	22,245	13,059	21,287	21,101

[1] Snakehead stocked during January and February [2] Tilapia fry constituted 90-95% of these totals

While stocking strategies were broadly adhered to in terms of species / life-stage combinations, *de facto* stocking densities were determined in part by the chronological availability and quantity of seed captured during individual fishing events. The day-to-day capture and survival of adult 'broodstocks' was especially unpredictable. Total fry stocking densities finally ranged from 5,540 - 22,245/ha (50% MWS) while 'adult' stocking densities ranged from 21-149/ha (Table 5.9). Highest densities of tilapia (fry and broodstock) and snakehead fingerlings were stocked in LUN. Although this design was limited in terms of reproducibility, it would prove of greater value as a scoping exercise in this first round of trials based on wild-sourcing.

5.6.4 Phase 2 collective management strategies and outcomes

The method adopted in the *a priori* design of collective management strategies mirrored that used in the phase 1 trials. However in this instance a summary of the phase 1 outcomes was also presented during inception workshops (section 3.2.1.3), following which their strengths and weaknesses were discussed in open sessions. Principle amongst the lessons emphasised by project staff, were the potential losses to production resulting from adherence to traditional collective (rather than staggered) harvesting strategies in the phase 1 trials; particularly in the smallest tank where stunting was clearly a problem. Furthermore, it was argued that spreading fishing effort over a longer period would reduce the incentive for poaching during the dry season, when potential for conflicts with bathers becomes most intense.

In addition to the earlier reasons given for reluctance to adopt staggered harvesting methods, it became apparent that the concept of carrying-capacity, and therefore the benefits of staggered-harvesting, particularly with respect to self-recruiting species, was alien and required careful analogous explanation to farmers who were most familiar with the intensive harvesting of short-duration annual crops. Familiarity with several local carp-stocking episodes only re-enforced this perception.

The threat of water-user conflicts emerged as another source of resistance; first between cultivators and fishers and subsequently between bathers and fishers as water levels fell. Technically at least, such conflicts could be effectively circumvented by the adoption of gear-restrictions supported if necessary by limited temporal restrictions. The most suitable fishing methods would preclude tank entry, e.g. gill net, seine-netting or cast-netting in favour of hook and line fishing from bund or littoral areas. Some participants, unwilling to use hook and line, suggested use of floatation devices (i.e. inner tubes) to periodically set gill nets; avoiding substrate disturbance. Catches could then be distributed around the village. This was generally felt to be impracticable due to the shallow depth and high levels of macrophyte occlusion encountered in smaller tanks. Conversely, hook and line fishing proved extremely efficient in terms of CPUE under the same conditions.

Over time, it emerged that underlying all these objections was a more fundamental problem; the threat to existing social hierarchies represented by formal revision of access rights. In LHG and GBW such sentiment was particularly strong amongst the main owners of irrigated land, i.e. village elites, although their objections were typically couched, i.e. 'collective-fishing would ensure the most equitable distribution of catches amongst all villagers'. In reality, better-off villagers were most likely to be deterred by social taboos associated with use of hook and line gears (section 5.2) and generally less inclined to participate in regular staggered subsistence fishing activity. Traditional collective events on the other hand also offered the possibility of generating surpluses which could be sold to generate institutional funds, which might also re-enforce the position of village elites.

This problem was least evident in the lowest caste village, MAD, where social cohesion was high; in large part due to their marginalisation by adjacent higher-caste communities. The situation in LHG was more complex, due to internal social divisions described in Chapter 4. The village was clearly divided into two geographically separated *variga* groups, which were further divided along a clear generational divide (Chapter 4). The 'poorer' group, living adjacent to the tank, had greater dependence on subsistence fishing, yet lacked the confidence and cohesion to organise for mutually beneficial collective action. As will be discussed, such attitudes and divisions presented great difficulties in effectively canvassing and representing the opinion of those currently most dependent on subsistence fishing.

Fishing societies, consisting of three executive and other ordinary members, were again formally constituted in each village (a typical constitution is shown in Appendix 34). With their low population sizes, it was decided in GBW and MAD that all households would be members, and management strategies would be periodically reviewed during monthly DDS meetings. In MAD and GBW, the fishing societies (FS) would cooperate with FO to promote *Shramadana* events and rule compliance, i.e. infringers would face restrictions on irrigation releases. In practice the latter sanctions proved impracticable and were not enforced. However, in both villages participation in tank-related *Shramadana* events, such as the clearance aquatic macrophytes and bund vegetation, was successfully linked to fishery access.

In the LHG FS, membership was limited to 15 poorer households, mostly with younger male household heads. Better-off householders, many with external salaried jobs (Chapter 4) were uninterested in the fishery *per se*, but were concerned with the possibility of incorporating poorer youth into the social fabric of the village. This group failed to produce any formal written constitution.

In every case, lack of consensus over staggered harvesting, meant that decisions were delayed until stocks began to reach to a harvestable size, i.e. at least 4-5 months after stocking. Village institutions were finally compelled to come to some decision, beginning in April 2001 when individual exploratory fishing took place alongside spill-fishing. The unusual hydrological conditions associated with the reversed monsoonal pattern (Chapter 3), meant this period coincided with the first full irrigated cultivation under most of the tanks for many seasons (Figure 5.14). Therefore, for many households irrigation became a priority and for some a pretext to further delay decision making, i.e. citing the risk of fishing-related percolation losses (Chapter 2: section 2.3.1.1). This was clearly an untenable position set against the rapid rate of natural percolation / evaporation losses at this point in the storage cycle (Murray 2004b, Appendix 21). However this information was not available to present to villagers at the time and the perception undoubtedly remained real.

Part of the reason for the inertia was that medium and better-off households, who were more likely to support tighter regulation or extended bans on fishing, were better represented at decision-making forums (Table 5.10). Moreover they were likely to hold most executive positions and dominate discussion in open session. Some 9,8 and 4 ‘influencers’, defined as those individuals making repeated contribution to discussions, were identified in three meetings held in MAD, GBW and LHG respectively during early June 01. Of these participants four in MAD, only two in GBW and none in LHG belonged to poorer households.

An impromptu opportunity to bring these two lobbies together in GBW arose when a conflict over unsanctioned fishing was witnessed by the village tank. Both parties were invited to try and resolve the dispute at a planning meeting on the same day. The fishers expressed frustration regarding their inability to influence decision-making, and felt that this problem extended into other areas of village life. Their lack of representation also reflected itself in the make up of the FS executive, the president of which proved particularly uncompromising and prone to confrontation. His view was that any commercial activity would rapidly deplete the fishery prior to any collective fishing; citing the fact that several boys had already sold part of their catch in the village on several occasions. However, the right to use non-intrusive fishing methods (hook and line fishing) from the bund for daily subsistence was finally conceded; though, a further 2-week extension of the ban (until a formal follow-up meeting could be organised), was effectively a face-saving measure for the FS president. Thereafter, staggered harvesting periodicity and the numbers participating would largely be determined by CPUE returns to hook and line (section 5.6.8). For this reason, group fishing gradually gave way to more individual effort as the season progressed. During the period of tank filling as the rains began (inundation), highest CPUE was achieved in shallow littoral grassy areas where fish move to breed and feed. Inevitably some fishermen continued to operate in these areas, but this resulted in no further conflict.

Interestingly regardless of the research teams repeated stipulation of its role as facilitators, GBW villagers' nevertheless, endowed it with some degree of external authority. This elevated the team not only to the role of mediators, but potential enforcers as evidenced by attribution of posters announcing the temporary ban on fishing (described above) to the FS and ' the research group'! In other words, we the researchers had, to some extent, also become actors in the trial

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Table 5.10 Attendance audits of death-donation society / fishing society joint meetings in three trial villages, June 2001

Village	MAD	GBW	LHG
Date of meeting	10 6 01	7 6 01	1 6 01
No. male BO[1]	3	3	4
No. male M	7	6	9
No. male P	7	6	9
Total No. males	**15**	**15**	**22**
No. female BO	3	1	2
No. female M	7	3	7
No. female P	9	2	4
Total No. females	**14**	**6**	**13**
No. 15 -20yrs	6	4	8
No. 21-30yrs	11	9	11
No. 31-50yrs	14	7	10
No. >50yrs	5	1	6
Total No. households	**36**	**21**	**35**
% All BO households	75	100	85.7
% All M households	82.4	90	76.2
% All P households	61.5	72.7	68.4
% All households	**70.6**	**84**	**74.5**

[1]Wealth ranks: BO = Better-Off, M = Medium, P = Poor

MAD became the first village to formally sanction staggered-harvesting following a meeting in early June. Conditionality was limited to gear restrictions, i.e. hook and line, and village residency. No attempt was made to impose commercial or spatial restrictions; both bund and littoral fishing were permissible. This outcome was extremely pragmatic both in terms of potential for rule enforcement and as a highly realistic mitigation response to water-use conflict potentials.

In addition to the greater social cohesiveness of this community, with its strong and broadly accountable leadership, one other factor also predisposed a consensual outcome. Of all the tanks KBW and LUN had the most central village locations, with many households over-looking them. This increased their quality of ‘observability’, i.e. any rule-infringement would be rapidly observed and offenders subject to public sanction. In none of the other three villages did any households directly overlook the tank, thereby increasing potential for free-riding.

LHG had least success in formulation of coherent management strategies. Despite its active and well run death donation society very of few of the younger fishermen would participate in any regular institutional activity. Even individual household visits failed to solicit opinion regarding collective management strategies from these youth. This reticence correlated with the higher (intermediate) caste-status of the village as well as the marked internal social division referred to above. These factors appeared to strengthen social taboos and the association of subsistence fishing with deviant/ anti-social behaviour. Intra-household conflicts amongst poorer household members were also clearly apparent on this issue. Several wives opined that once married they expected their husbands to refrain from regular fishing activity as this is associated with the consumption of liquor by groups of 'underemployed male-youth'.

Consequently, despite regular meetings, little effective action ever took place and the fishery progressively moved towards an open access regime (Plates 5.7); with external villagers, including some from MAD taking advantage of the disarray. Livestock holders from neighbouring villages also exploited this lack of resolve by bringing their buffalo to wallow in the tank during the dry season (Plates 5.7 A and B). This compounded the water quality deterioration, resulting in the loss of 5-6 weeks of bathing amenity in the village. A further indirect conflict resulted when a large number of women from the village began to bathe at a site in a neighbouring village informally restricted to priests from a nearby temple. A similar post collective fishing problem was reported in GBW but on this occasion due to caste polarisation with, a neighbouring community (Ralapanawe – Chapter 4).

A

B

Plates 5.7 A and B: The combined effects of unsanctioned gill-net fishing by local youth (A) and water buffalo from a neighbouring village (B) result in a reduced water quality and protracted loss of bathing amenity, LHG tank July 01

Some form of collective or mass fishing finally took place in each of the tanks, though these were relatively low-level events; their yields supplementing staggered harvesting rather than the other way around. Villagers in MAD, after repeatedly delaying a decision on CF, were finally content to let those most reliant on subsistence activity informally organise the events. These lasted for only 1 day in KRB and 3 days in LUN, both in October. In other words because of periodic harvesting, CPUE levels did not rise sharply in the usual fashion; CF events were therefore small and delayed until the very end of the dry season when only muddy residual pools remained. This even distribution of effort and yields also had two other very beneficial consequences: (1) CF resulted in negligible bathing disruption or associated conflict. This is significant as the same household proximity associated with the tanks 'observability', also elevated their role for bathing and other domestic purposes. (2) Villagers were reliant on their own gears throughout, meaning that the entire production from these tanks remained within the village. This outcome can be contrasted with that in HNG (3.5ha MWS) on the periphery of MAD village (Appendix 28: A28.1), where no stocking took place and informal external participation increased during the dry season in the more usual manner.

Neither of the events in the other two villagers escaped conflict. Collective fishing in GBW was unilaterally initiated by one of the poorer subsistence fishermen, who invited friends with gears from a neighbouring village to participate during August. This also reflected unresolved antagonism between the FS executive and regular fishing participants. The activity was finally curtailed by a widely respected elder member of the community (a retired FO president) who helped re-impose a ban on the use of nets after 3 days.

The adverse consequences of poor management in LHG have been discussed above. Here the use of nets began to increase regardless of sanction as water levels decreased, culminating in low level mass fishing over 4-5 days as early as July, with no semblance of collective organisation. CF in SER followed the previous year's pattern, i.e. prompted by the risk of a fish kill following lift irrigation in August.

No formal CF yield re-distribution took place in any of the villages, though in each case observers from the bund who requested fish were given a small share and surpluses were also gifted to other extended family members and neighbours (Chapter

6). Surpluses were insufficient to generate institutional funds in any of the villages. While there was general satisfaction with the staggered harvesting outcome in MAD, the lack of surplus was disappointing for the village elites in GBW for whom this had always been a primary incentive.

A small amount of informal fishing effort continued post CF in the two larger tanks, GBW and LHG. In LHG this took place at night, prolonging the conflict. In GBW it was restricted to hook and line fishing and mud and hand-fishing by children for gouramy in littoral areas. Such low level subsistence activity was restricted to 2-3 of the poorest families in the village (Chapter 6: section 6.2.10). Even though the practice continued to have some negative impact on water quality, it was tolerated sympathetically by others in the community because of the poor status of the group.

5.6.5 Phase 2 adaptive learning and impact monitoring strategies

The outcome of the adaptive learning process (Chapter 3), is readily apparent from a comparison of the *a priori* intentions of two of the communities, expressed in their fishing society constitutions (an example is shown in Appendix 34) with the final management outcomes documented above. The decision to defer collective harvesting in MAD is one clear example.

Of particular interest to villagers in these forums, were comparisons of mean *per capita* fresh fish consumption from tank and commercial sources expressed in cash equivalents, i.e. levels of income substitution attributable to tank stocking. Such comparisons were most graphic in MAD where all production from LUN and KRB could be attributed to stocking interventions (Chapter 6).

5.6.6 Production characteristics

A summary of yield outcomes based on data assembled from direct observation and key informant sources (Chapter 3: sections 3.5.1 and 3.5.2) are presented below. Despite the use of multiple techniques it proved impossible to be sure of logging entire yields and consequently, estimates are likely to be conservative. In all cases, recording was most difficult during the staggered harvesting periods when fishing is more impromptu and events temporally dispersed. Other background variables related to the size of tanks and their respective communities, their remoteness and the ability of local communities to reach consensus regarding different types of fishing practices.

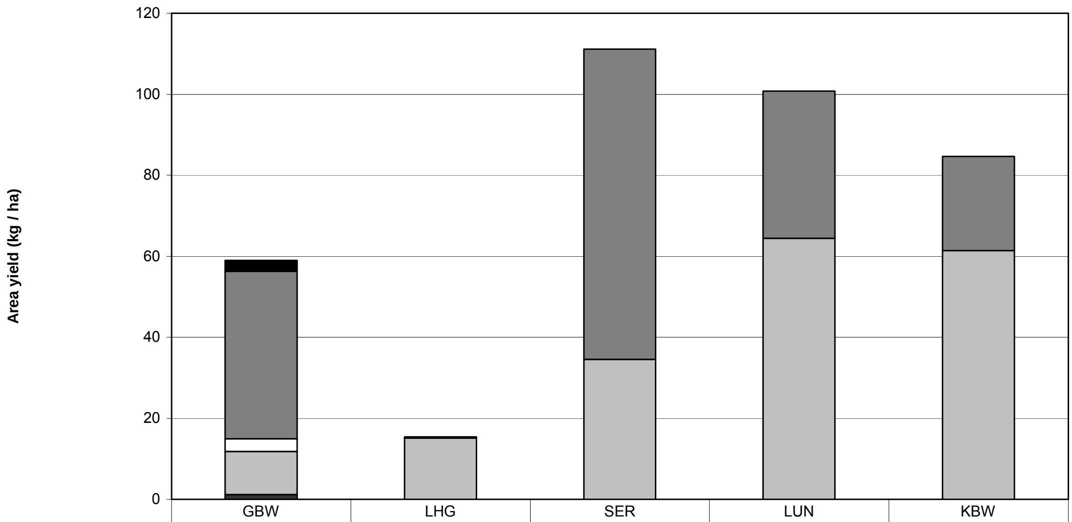
Taken together, these factors mean that overall; under-reporting is likely to be most marked in LHG, where much fishing activity was undertaken in a covert and unilateral manner. Conversely the most comprehensive records were obtained in LUN and KBW small and highly visible tanks within the heart of the Maduragama village where all fishing was practiced openly.

In Figure 5.7 yields are differentiated into fishing periods associated with dominant seasonal gear types (section 5.2), while monthly yields of the five principle food fish varieties harvested from the tanks are presented in Figure 5.8. Results indicate highest productivity in the three smallest tanks (Table 5.11), while the lowest level of 15.4 kg ha^{-1} was recorded in LHG. Of the three highest yielding tanks, two; SER and LUN (both comparably sized at 3-4 ha MWS), recorded yields in excess of >100kg ha^{-1}. Although the LHG yield estimate is probably excessively low, broader differences between the other tanks appear consistent with a number interacting production factors; stocking density, prey-predator interactions, nutrient status and harvesting strategies.

Table 5.11 Summary of production outcomes from phase 2 trials

	GBW	LHG	SER	LUN	KBW
Surface area at FSL (ha)	13.56	8.42	3.25	3.79	1.89
Total Yield (kg)	254.3	104.7	181.2	198.6	83.1
Area yield (kg ha^{-1})	59	15.4	111.1	100.7	84.6
% Staggered & spill-fishing	24.5	98.2	31.1	58	72.5
% Collective & test netting	75.5	1.8	69	36	27.5
Yield (g) per stocked seed	12	5	13.9	8.9	15
Onset of staggered (ii) fishing	5 Jun	8 Jun	1 May	11 Jun	11 Jun
Date of collective harvest (CF)	28-29 Aug	26 Jul – 1 Aug	20 -21 Aug	6-8 Oct	29 Sep – 1 Oct
Grow-out time to CF (wks)	39	32.4	36.1	44	40.7
Snakehead : tilapia yield ratio	1.64	NC	0.43	0.18	0.09
Mean tilapia specific growth rate (SGR)	(1.69)[1]	1.78	1.83	1.28	1.45
Mean snakehead specific growth rate (SGR)	NA	NA	NA	2.11	1.89

[1] Value influenced by resident stocks



	GBW	LHG	SER	LUN	KBW
Staggered (iii)	2.7				
Collective-fishing	41.4	0.3	76.6	36.3	23.3
Test-netting	3.1				
Staggered (ii)	10.6	15.1	34.5	64.4	61.3
Spill-fishing	1.2				

Figure 5.7 Area yield outcomes (50% MWS) associated with different fishing periods in five stocked village tanks; phase 2 trials, Apr – Oct 2001

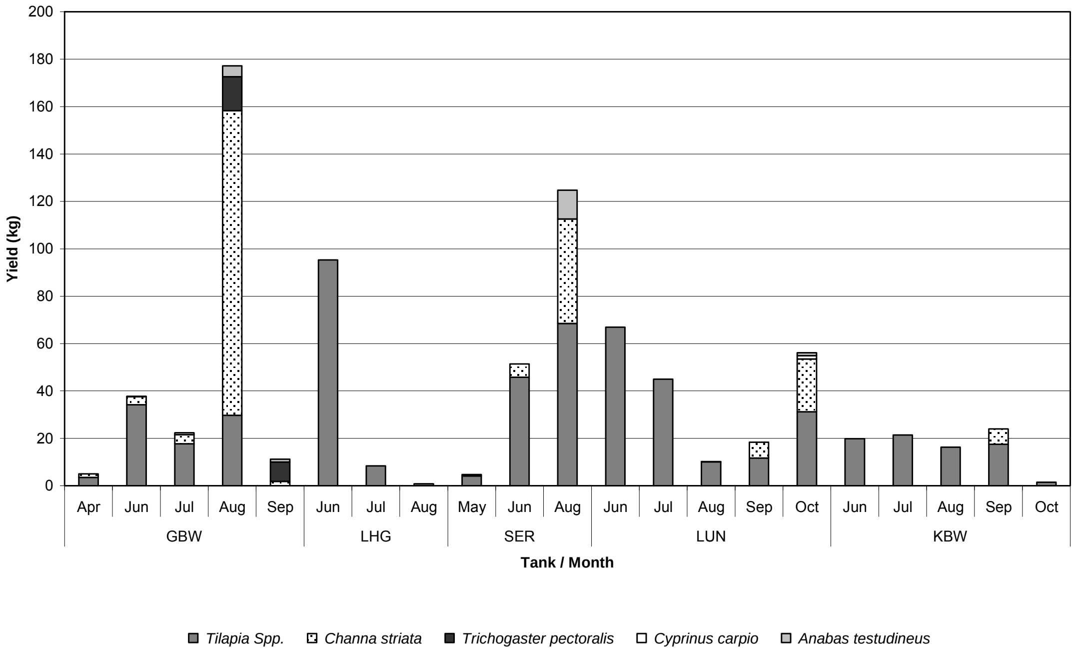


Figure 5.8 Monthly yields of principle food fish varieties harvested from five stocked five village tanks, phase 2 trials, Apr - Oct 2001

Yield outcomes are broadly in proportion with fry stocking densities, i.e. 8,000 to 11,000/ha (50% MWS) in SER and LUN respectively, while only 3,000/ha were stocked in LHG (Table 5.9). Furthermore, SER received relatively few tilapia adult ‘broodstocks’; 18/ha (50%MWS), compared with 129/ha in LUN. This suggested that grow-out of stocked fry was more significant than *in-situ* production in these tanks.

Subsequent standing stock levels were a function of fish mortality and growth rates. Mortality would have been mostly due to predation and fishing pressure in these brief production periods. Snakehead proved relatively resistant to the most common staggered harvest method using hook and line baited with worms or bread, responding to live-fish baits instead (Figure 5.8). As the collection of such baits requires greater effort than the use of worms it is a less common practice. Consequently, snakehead predation is likely to have increased steadily during the grow-out period until finally they too became susceptible to gill-netting during collective harvests.

Such predation pressure was greatest in GBW; the only tank with a resident adult snakehead population at the time of stocking. This culminated in a snakehead: tilapia yield ratio1.6:1 (Table 5.11), which undoubtedly contributed to the relatively low total recorded yield (59 kg ha^{-1}). This finding was also substantiated by the relatively large mean size of harvested tilapia; 155g compared to 74 - 127g in the other tanks (Figure 5.9 and Figure 5.10). The high ratio also indicates that other SIS must have constituted a significant proportion of the prey consumed.

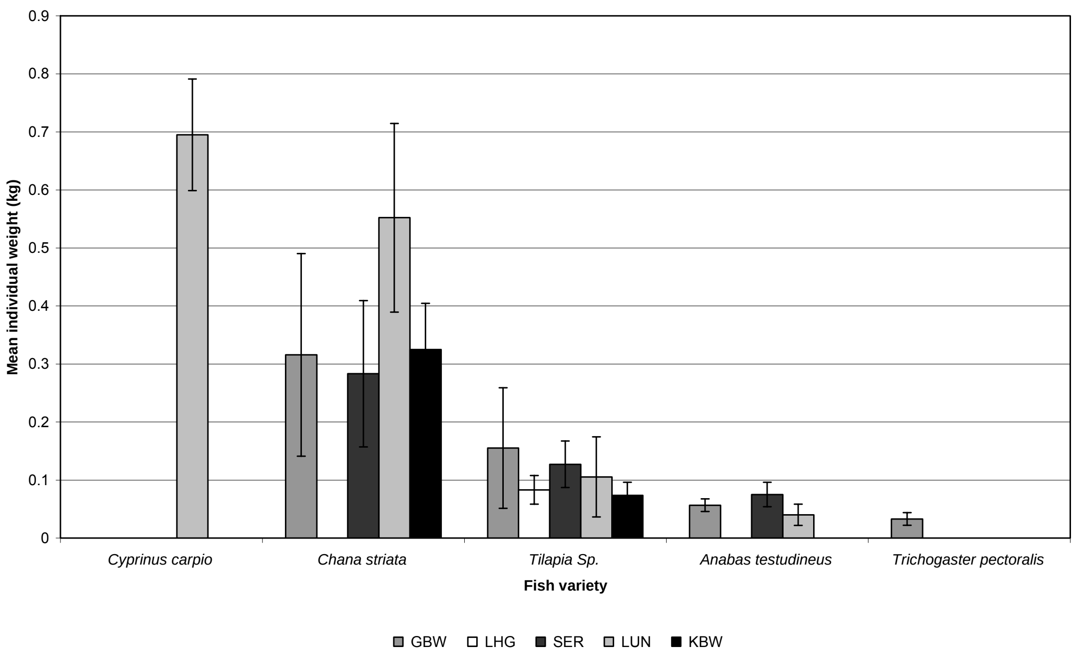


Figure 5.9 Mean weight and standard deviation of fish harvested from five stocked village tanks; phase 2 trials Apr, Oct 2001

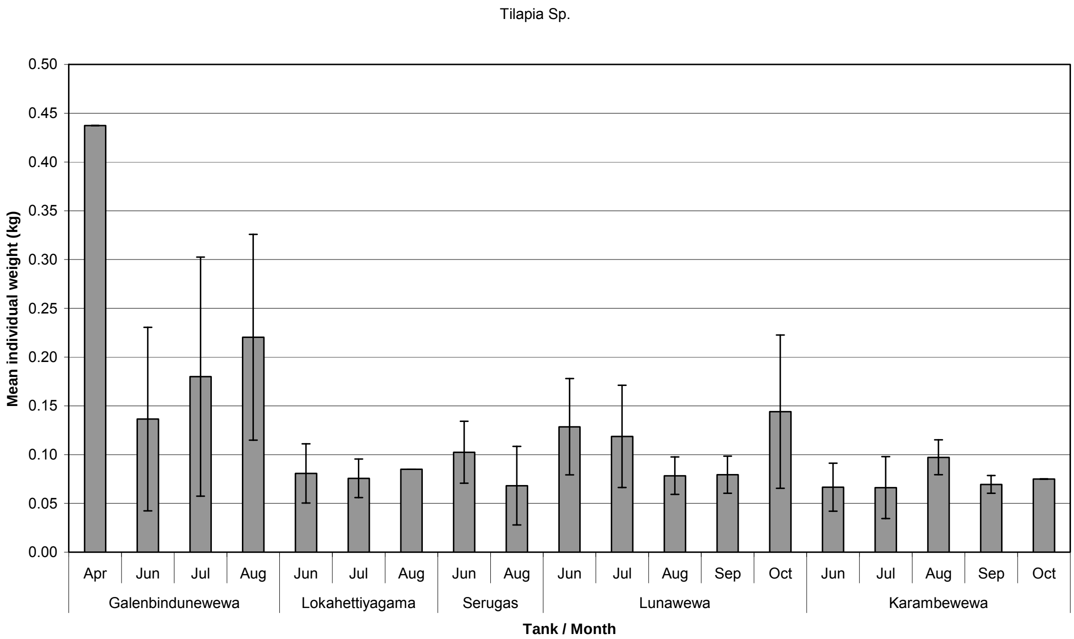


Figure 5.10 Monthly mean weight and standard deviation of tilapia harvested from five stocked village tanks; phase 2 trials, Apr – Oct 2001

Predation pressure was also relatively high in SER (0.43:1 prey, predator yield ratio). However here, adult snakehead only migrated to the tank during the April spill event, facilitated by the tanks 'free-fall / contour' weir (Chapter 2). By this time, many of the fry stocked would have grown to a more predator-resistant juvenile size. Lower yield ratios in LUN and KRB indicated that snakehead harvests consisted primarily of stocked fish (snakehead nests were observed only in GBW and SER (Plates 5.8A). No snakehead harvest was reported in LHG, where only a negligible number had been stocked and a sizeable weir precluded upstream migration of fish. However during September, intensive predation pressure from a mixed avifauna of herons and egrets numbering over 120 individuals (which were concentrated in the tank over a 3-4day period), probably curtailed post collective harvest 'staggered (iii)' fishing (Plate 5.9).

A **B**

Plates 5.8 A and B: Breeding activity in SER tank, post-*yala* spill 01: (A) a shoal of juvenile snakehead (*petav pola*), 5-6 weeks old – foreshore area 21 May 2001; the mother, not visible, guards the shoal (B) closely spaced breeding nests ('leks') patrolled by male tilapia – bund area 27 June 01

Plate 5.9 Intensive predation pressure from egrets and herons in residual water storage of LHG tank, September 2001

5.6.7 Growth rates, stunting and survival

It was difficult to assess growth rates with a high degree of certainty for the following reasons (1) because of the mixed population of fry and adults used for stocking (2) the unquantifiable extent of *in-situ* breeding. However, to give some indication, tilapia and snakehead specific growth rates (SGR) were calculated based on a weighted mean start weight (considering both fry and juvenile size) and weighted mean size at harvest (Table 5.11).

Results indicate slowest growth in LUN. This was probably due to over-stocking which resulted in a degree of stunting early in the grow-out window, before snakehead predation and fishing pressure increased mortality. In MAD, by the month of May the problem was evidenced by both the large number of small individuals caught during test fishing and an extremely high nest density; 1-2 per m^2 in littoral areas. Individuals caught during test fishing weighing between 23g-34g, were also observed mouth brooding.

Nest density in SER, the next most densely stocked tank, but with a larger snakehead population, was considerably lower at 1 per 2-3 m^2 (Plates 5.8B). The superior yield performance here suggests a more optimal stocking density (8,000 fry/ha).

Further insight into tilapia growth performance was derived from an analysis of length - weight relationships, calculated as condition factors (CF). Data from both test fishing and participant direct observation were used for the analysis (n = 1,020). Condition factors are also inversely related to fish size, i.e. smaller fish have higher condition factors. To eliminate this factor in order to reveal the effects of environmental variation, CF results were regressed (Equation 5.1) and individual residuals (observed minus predicted values) calculated.

Equation 5.1 $y = 10.807 x^{-0.5548} (R^2 = 0.257)$

The smallest fish (< 6cm), with the most non-linear standardised length-size relationship, were also excluded from the analysis. Mean monthly residuals are shown in Figure 5.11; where values greater and lower than zero indicate above and below average CFs respectively. In all tanks clear troughs and peaks in CF are apparent around the major period of inundation between March and May. This trough is probably due to the negative impacts of high turbidity levels on nutrient status during inundation (Murray 2004b), while the peak is probably associated with improved nutrient availability in submerged littoral areas immediately post-inundation (when turbidity levels have decreased). This finding has implication for stocking strategies; the larger fish are prior to inundation, the greater will be the cumulative yield gain during this period of accelerated growth. The benefits of early stocking or stocking advanced fingerlings are therefore clear.

Only the high positive mean residual value recorded in LUN during May (relative to the other tanks) is inconsistent with the elevated incidence of stunting described above. This is probably due to a bias imposed by the extremely large number of smaller individuals caught in this tank during test fishing. Despite the regression correction this still influenced the weighted mean.

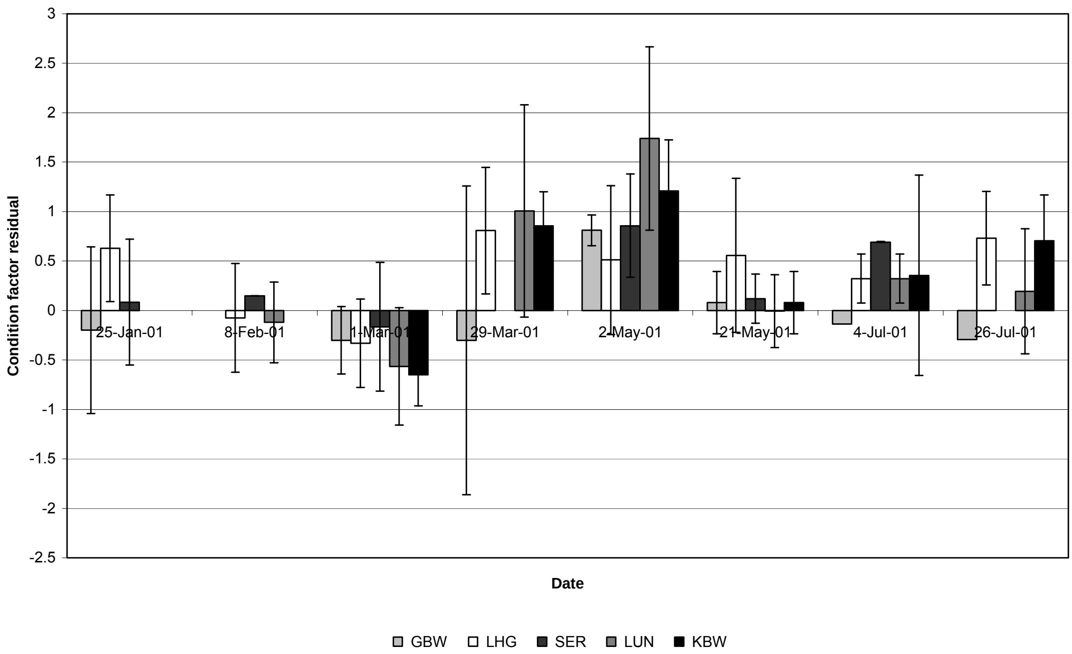


Figure 5.11 Mean difference and standard deviation between observed and length-regressed tilapia condition factors from test-fishing events in five stocked village tanks; phase 2 trials, Apr - Oct 2001

5.6.8 Participation, CPUE and yield distribution

Over the entire fishing period from April to October 2001; members of at least 84%, 19%, 35%, 30%, and 24% of local community households were recorded fishing in GBW, LHG, SER, LUN and KBW tanks respectively (a total of 43% of households in MAD fished in either LUN or KBW). The high proportion in GBW reflects the small size of the community relative to the resource. However, in both GBW and MAD the absolute number of households exploiting the stocked tanks were the same; 21 households in each case. Although this number represented a lower proportion of the larger MAD community, the exploitation of the smaller combined resource of LUN and KBW tanks was much more intense, i.e. staggered harvesting was clearly more effective in terms of the total numbers of families participating (Figure 5.12), fishing periodicity (Figure 5.13) and yield (Figure 5.14). Participation and yields in LHG were lowest, but likely to be under-reported for the reasons outlined above (section 5.6.6). Only GBW retained enough residual water to facilitate a limited amount of 'post-collective harvest fishing, mostly by children from the poorest households.

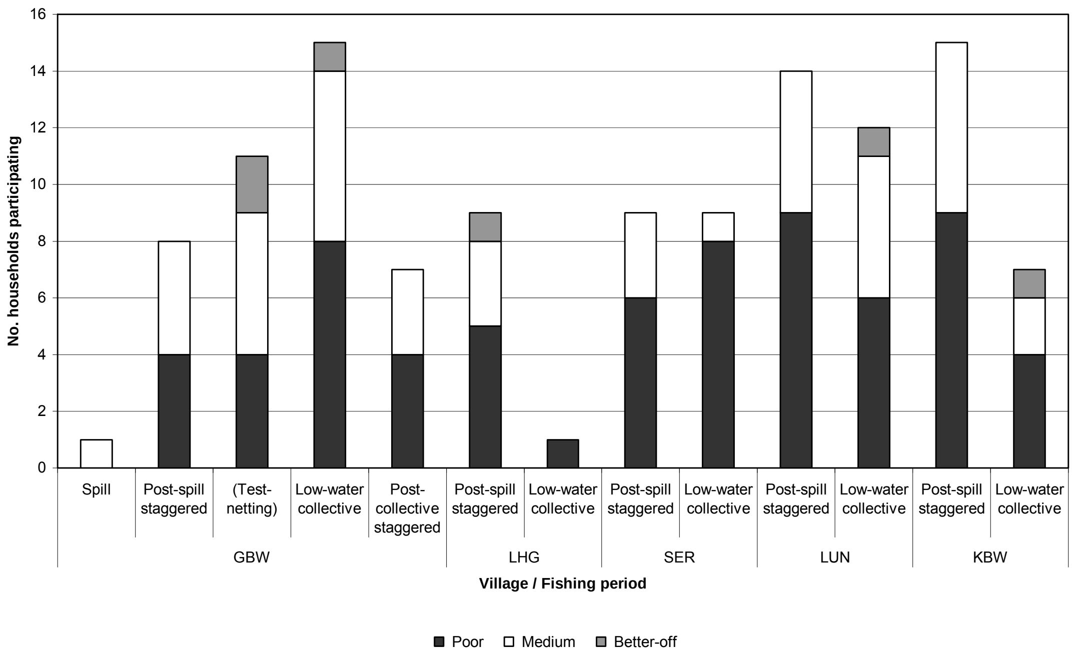


Figure 5.12 Total number of households with members participating in fishing activity in five stocked intervention tanks during seasonal fishing periods, Apr – Oct 2001

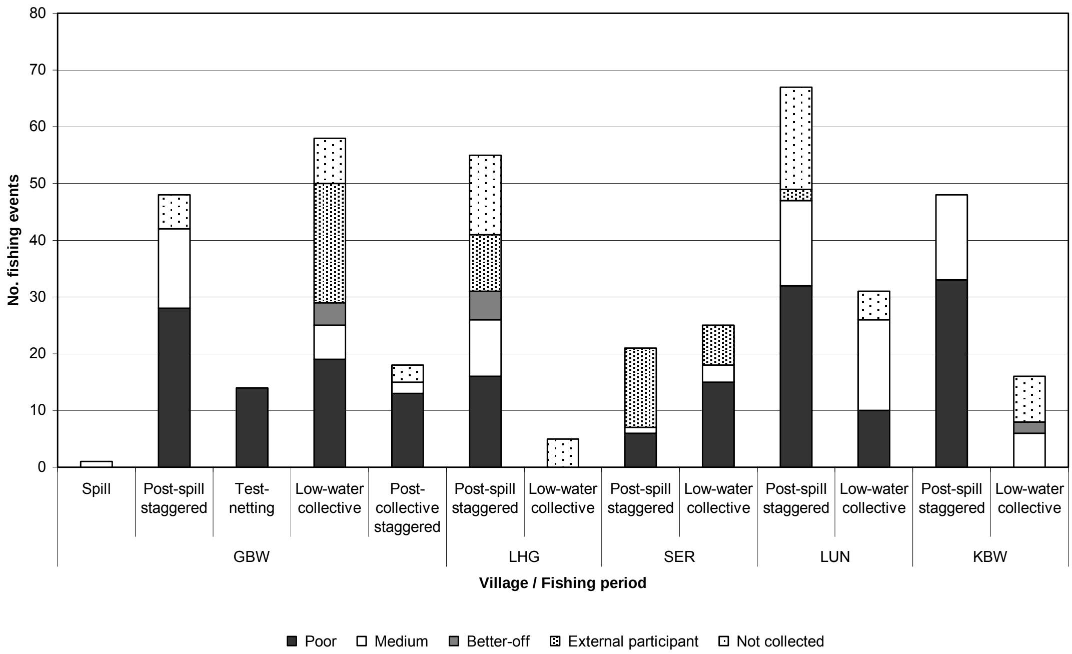


Figure 5.13 Frequency of fishing events by different wealth groups during different fishing periods in five stocked village tanks, Apr – Oct 2001

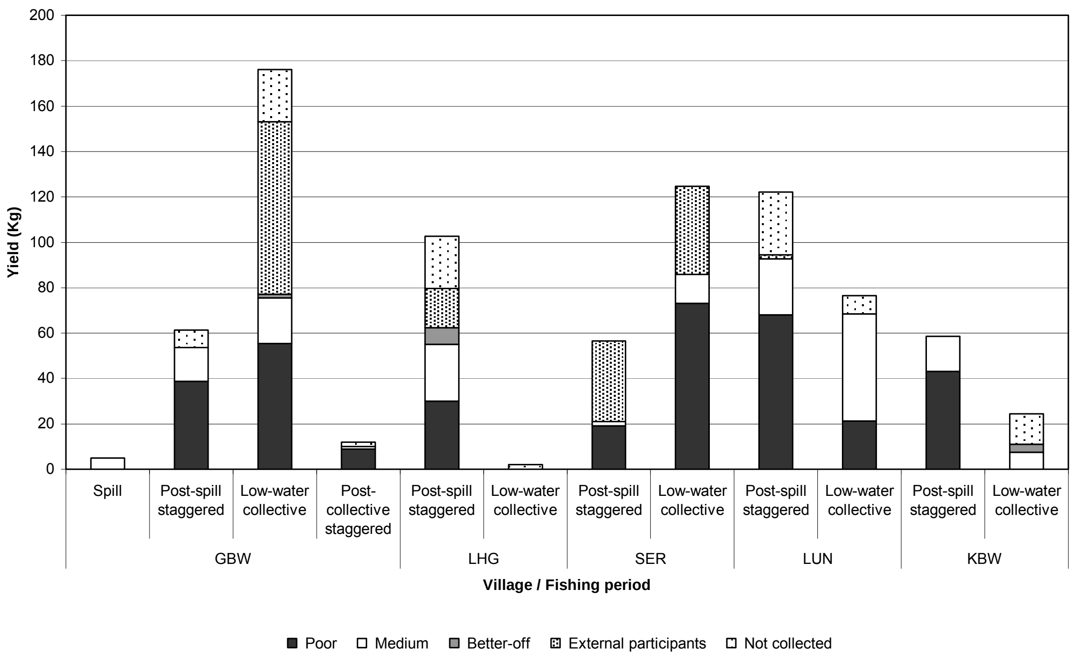


Figure 5.14 Total yields harvested from five stocked village tanks by different wealth groups during seasonal fishing periods, Apr - Oct 2001

As in phase 1, fishing effort was dominated by poor and medium wealth households, with better-off participation essentially restricted to collective events including test-netting in GBW. Consequently, poorer households also derived the greatest relative benefit from staggered harvesting.

While external participants were almost entirely excluded from LUN and KBW, such activity in the other tanks resulted in a significant 'loss' of yield to the respective local communities. This was most evident in GBW, where, due in part to an unresolved conflict between different interest groups almost half the collective-fishing harvest went to external participants (A B
Plates 5.10B, section 5.6.4). However, although more fish may have been retained through improved cooperation; the effort and gears available within the village were in any case unlikely to have been sufficient to achieve reasonable CPUE in this larger tank without some degree of external participation. Furthermore, much of this effort came from two nearby similarly low-caste villages where significant reciprocal participation was reported.

A B

Plates 5.10 A and B: GBW collective fishing, Sep 2001; (A) project staff assessing net characteristics (B) A boy from neighbouring Ralapanawe village, with his family net, shows share of catch.

Viewed from this perspective, the export of this production should not be viewed as a loss but as a form of mutually beneficial intra-community cooperation. This brings greatest benefit to the poorest groups, as some medium, and most better-off households are unlikely to participate in any fishing activity beyond collective harvests in their own tank(s). By contrast, much of the external fishing in SER and

LHG was undertaken by lower-caste participants from Maduragama on an informal and non-reciprocal basis.

As demonstrated in the phase 1 trials, CPUE rather than standing stock levels *per se* are a major determinant of villager's propensity to participate in fishing activity. CPUE levels were highest at any time in phase 1 or 2 trials (2.5 kg person^{-1} hr^{-1}), during a brief spill-period in GBW when migrating fish were caught by groups and individuals employing a variety improvised gears. Around 20 - 25 male villagers from 10-15, mostly poorer households, participated over 7 days of viable spill, harvesting a total of 50 - 75kg of fish (mostly tilapia ranging 25 - 100g and smaller numbers of snakehead ranging from 0.1 - 0.5kg).This reflects the ease with which fish can be caught during these periodic 'windfall' events (Figure 5.15). Low intensity spill events preclude similar effort in the other stocked tanks.

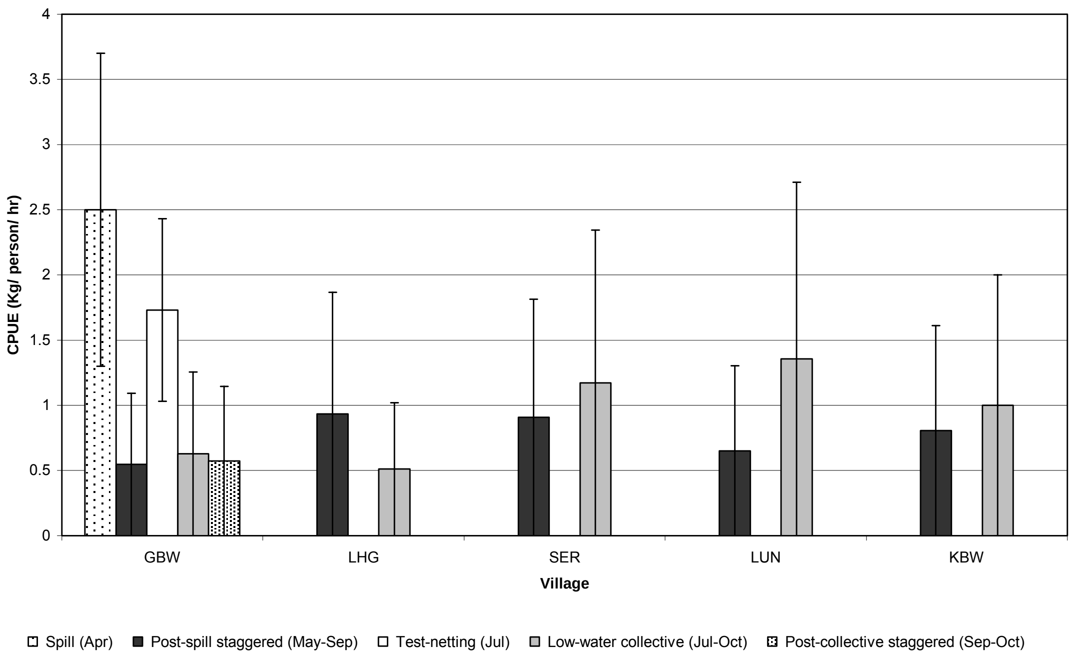


Figure 5.15 Mean CPUE and standard deviation during different fishing periods in stocked five stocked village tanks, Apr – Oct 2001

Staggered harvesting with hook and line resulted in mean CPUE from 0.55 - 0.95 kg person^{-1} hr^{-1} in the different tanks. This corresponds with the finding in phase 1 that a minimum CPUE level of around 0.5 kg person^{-1} hr^{-1}, is required to motivate sustained subsistence fishing by mostly poorer households. Contrary to expectation; in most cases mean 'staggered' CPUE was only marginally lower than that recorded for 'low-water collective fishing' events (0.51 – 1.36 kg person^{-1} hr^{-1}). Furthermore, the greater frequency and periodicity of staggered events meant such activity was of far greater significance to basic household food security, again, especially for poorer households (Figure 5.14). Mean monthly 'staggered' CPUE levels were highest during June and July (0.59 – 1.1.4 kg person^{-1} hr^{-1}) when tanks still contained significant shallow submerged littoral areas in which hook and line fishing was highly efficient (Plates 5.11 A and B). Thereafter, CPUE levels fell to 0.33 – 0.69 kg person^{-1} hr^{-1} during August and September, which in turn lead to a fall in the frequency of fishing events.

A **B**

Plates 5.11 A and B: Early morning hook and line catches of tilapia and snakehead from recently inundated littoral areas of GBW tank, two weeks post-spill, May 2001

In making the above assertion regarding net gains, the extent to which staggered harvesting may have lowered collective-fishing yields must also be considered. Comparison with the phase 1 intervention outcome in SER indicates that although CPUE fell from 1.65 - 0.91 kg person^{-1} hr^{-1} there was actually a marginal increase in the total CF harvest from 122.5 - 125kg. Total production inclusive of staggered harvesting increased by 47.8% (from 75.4 kg ha^{-1} - 111.1 kg ha^{-1} at 50% MWS). This increase can be attributed to the combination of modified stocking regime and staggered harvesting. Although staggered harvesting was ultimately curtailed (section 5.6.4), levels still represented an increase on the previous year's recorded levels. The result therefore suggests that staggered harvesting does indeed lead to increased net productivity gains.

Although no similar control was available in the other tanks, similar gains are likely to have been highest in LUN and KBW where staggered-harvesting was most intense (Figure 5.13). Other findings (Figure 5.14) also indicate that due to the lower carrying capacity of smaller tanks; the relative contribution of collective harvests and staggered harvesting fall and rise respectively with decreasing tank size. The effect is most marked in the smallest tank KBW, where staggered harvesting produced at least three times the collective yield. Key informants reported that in the past, this tank had yielded only very small quantities of 'stunted' fish.

For the most part staggered yields were relatively small, with participants fishing only as long as required to meet their immediate family's consumptive needs. As in phase 1, surpluses were only generated during collective harvest periods. Again the small size of such surpluses meant they were either dried for later household use or distributed amongst extended family.

Only in GBW did key informants report any commercial transactions. This was undertaken on a small scale by several young boys who regularly caught 4 - 5 kg per day during the early post-inundation staggered fishing period. Sales were confined exclusively to the immediate community at substantially discounted rates. While some non-participating households benefited from this low cost production; the practice appeared to fuel discontent amongst a number of better-off families, who felt they were being excluded from future potential commercial benefits (section 5.6.4).

5.7 Summary

The phase 2 results presented above indicate that stocking based on local sourcing followed by the promotion of staggered harvesting strategies appeared to selectively benefit poorer households. Furthermore, such benefits became more marked in smaller tanks with lower carrying capacities.

As indicated above, the difficulties associated with collecting such temporally dispersed data necessitated triangulation of multiple data gathering techniques. In the next chapter the outcomes of these more direct observational and key informant techniques are contrasted with the outcomes of a longitudinal wealth stratified consumer survey.

To gauge the likelihood of sustainable adoption, it is also essential to canvas perceptions of both participant and non-participating community members. Accordingly the results of a participatory impact monitoring study undertaken at the completion of phase 2 trials, are also presented in the following chapter and compared and contrasted with the more quantitative measures discussed so far.

Chapter 6 Results of structured household questionnaire and participatory impact monitoring of phase 2 trials

6.1 Introduction

In Chapter 5, I described the results of two phases of action research based on simple stocking enhancements in village tanks. Emphasis was on evaluation of yield outcomes based on researcher direct observation, test fishing and key informant reports. In this chapter, the results of the phase 2 trials are triangulated with outcomes of social surveys where emphasis was on participant perspectives and how benefits or losses were distributed between different interest groups with in the villages. Such questions are more directly concerned with the likelihood of sustainable adoption of the intervention technologies. Returning to the livelihoods framework (Chapter 1: section 1.1.1), results are also interpreted from the perspective of a vulnerability context, e.g. cultural practices, seasonal and longer term trends and short term shocks that the poor may be particularly affected by. These contexts were established for the phase 1 and 2 research sites in Chapter 4.

Phase 1 trials indicated low potential for stocking tilapias in larger perennial tanks due to difficulties demonstrating yield improvements against a background of highly erratic natural production. Developing on this experience, phase 2 trials utilised wild-sourced seed and staggered harvesting options, to enhance production in the smallest seasonal village tanks accessed by low-caste communities in upper-watershed areas. Most of these tanks had dried completely and were therefore devoid of fish prior to stocking.

Results of two social surveys are presented: (1) from the food consumption and water-use components of a longitudinal (fortnightly) household livelihood questionnaire and (2) from a once-off post-intervention participatory impact monitoring (PIM) questionnaire. The second retrospective questionnaire was geared more specifically to the sustainability question and what modifications if any might be required to achieve this. This kind of monitoring was only carried out for the phase 2 trials, which necessitated a longitudinal component to evaluate staggered harvesting outcomes.

Both surveys were primarily wealth stratified, though household location, in relation to the intervention tanks, and intra-household variables of gender and age also influenced the design. An expanded group of 73 participants representing 57 households in the PIM survey in four villages also incorporated all of the 41 households who had already participated in the longitudinal survey. Precise methodological details are given in Chapter 3.

A total of five tanks belonging to four adjacent communities in the Giribawa research were stocked in phase 2. The focus of these trials was the lower-caste communities; one of these tanks, SER, belonged to a higher-caste *Goyigama* village and was not incorporated in the more socially orientated livelihood and PIM surveys. The repeat intervention in this tank was also for a more technical reason (Chapter 5). Conversely, while no stocking took place in GUR in phase 2, the village was incorporated in both social surveys as a low-caste, lower water-shed control (Chapter 3). The principle intervention sites were: Maduragama (MAD), Lokahettiyagama (LHG), and Galenbindunewewa (GBW). All were low-caste villages located in upper-watershed areas. Two tanks Lunawewa (LUN) and Karambawewa KBW) were stocked in MAD while one tank was stocked in LHG and GBW, each bearing the same name as the village. As in the previous chapter a suffix, e.g. LGH^t is used to distinguish tank from village when this is not contextually evident.

6.2 Results of longitudinal household livelihood questionnaire

Analysis begins with an assessment of seasonal household occupancy levels upon which subsequent *per capita* consumption calculations were based. I then go on to examine variation in meal frequency, inter-household food sharing habits and intra-household equity, before comparing consumption trends for inland fish and it's substitutes. Next, I examine the contribution of inland fish according to production source and go on to look at trends in supply and price for commercial production over the same period. Subsequently, I focus on the seasonal outcome of stocking interventions in three villages and contrast this with the contribution of subsistence production from 'other' non-stocked village tanks to consumption patterns. Finally, I investigate how the various varieties of inland fish harvested from stocked village tanks brought different benefits to different groups. Mean tank production levels were also extrapolated from these results and compared with the results presented in Chapter 5.

6.2.1 Household occupancy

The survey encompassed an average of 168 persons per fortnightly visit (based on a mean overall occupancy of 4.1 persons per household), with an average of 38.6 visits for each of the 41 households. Mean occupancy levels ranged from 3.4 - 5.1 according to village and wealth criteria; higher levels were generally associated with poor and medium wealth households. The same group also recorded higher seasonal variations due to their greater dependency on off-farm and remittance labour (Figure 6.1). Maximum occupancy levels of 7, 9 and 8 were recorded for better-off, medium and poor wealth ranks respectively. GBW, the remotest and possibly poorest village (Chapter 4) recorded the highest mean levels overall.

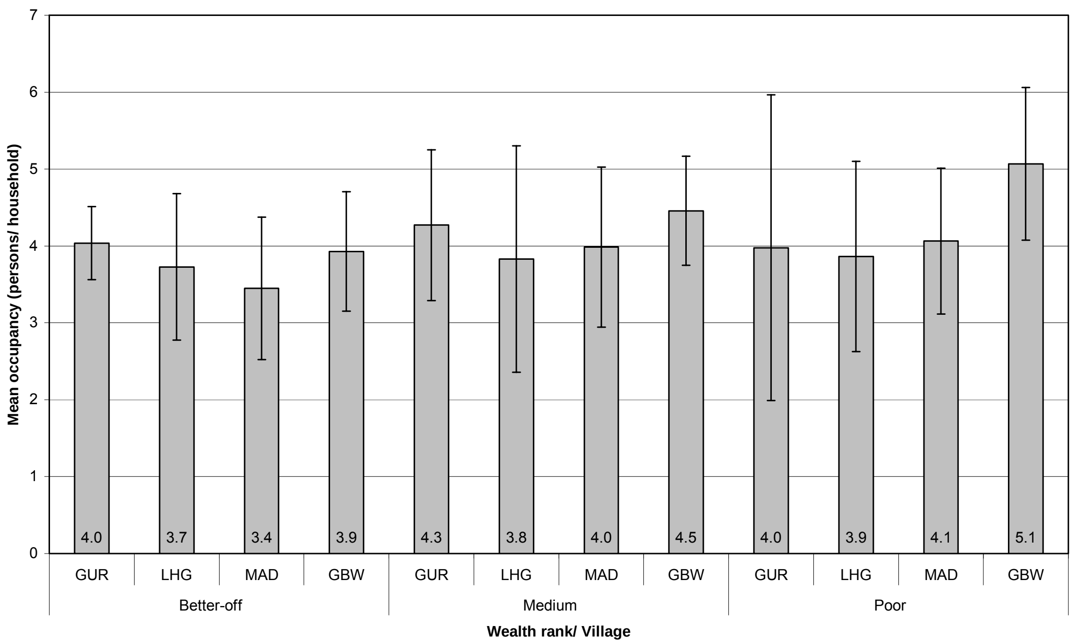


Figure 6.1 Mean household occupancy by wealth and village, showing seasonal standard deviations, Nov 00 - Dec 01

6.2.2 Meal frequency and sharing

Pilot PRAs indicated that meal frequency and inter-household meal sharing might be important coping strategies during periods of seasonal hardship (Chapter 4: section 4.3.15) with implications for indirect benefits arising from stocking interventions. Consequently, both practices were investigated in the longitudinal household survey.

In all villages, better-off and medium households always consumed three meals per day with very few exceptions. Consequently, only results for ‘poor’ households are shown in Figure 6.2. Results indicate a disparity between GUR village, where the poor also eat an average of almost three meals per day, and the other upper-watershed villages; LHG, MAD and GBW which exhibit seasonal variations with annual means of 2.7, 2.5 and 2.6 meals per day respectively. MAD and GBW (the lowest caste villages) are poorest in this respect. The lower meal frequency indicated for many poor households during almost every month of the year appears to be a coping strategy. Only one respondent; a single female headed household with a large number of young dependents in GBW was compelled to periodically lower meal frequency to one meal per day. Generally lowest overall meal frequencies or ‘hungry days’ occur prior to the *maha* harvest (Dec–Feb) and during the dry season (Jun-Sept).

Seasonal meal frequency is therefore highly consistent with the other indicators used in the wealth ranking exercise; housing status and educational achievement (Chapter 3). However, the latter two criteria are still more useful for this purpose, as they are can be more readily observed by key informants.

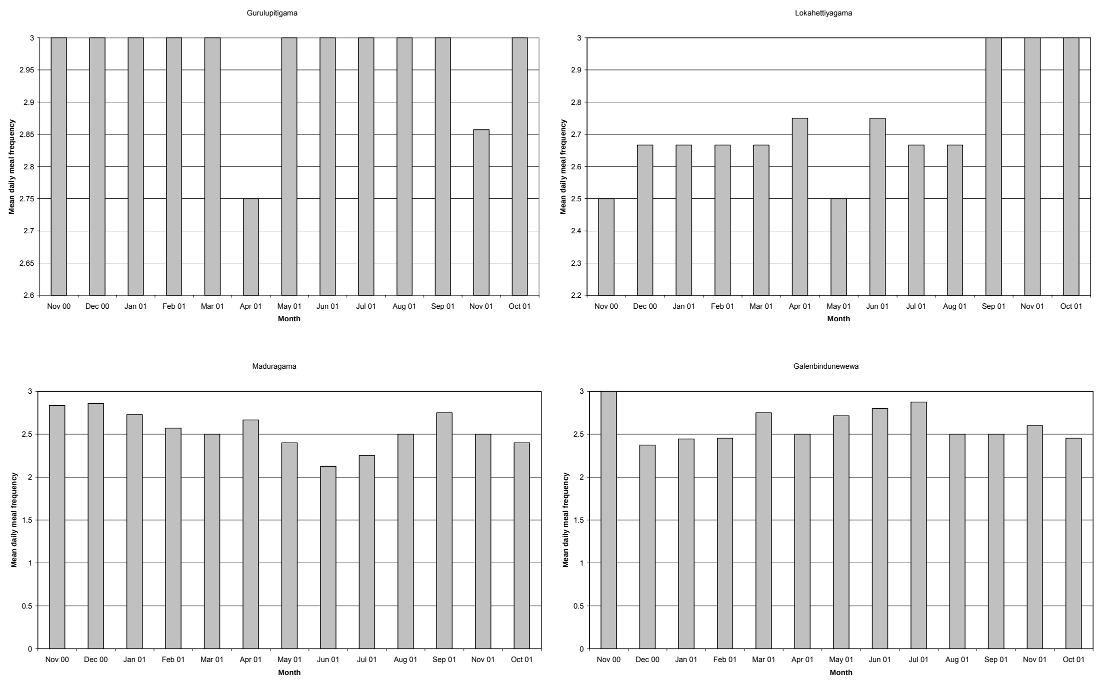


Figure 6.2 Mean daily number of meals consumed by 'poor' households in four low-caste villages, Nov 00 - Dec 01

Meal sharing behaviour showed less marked wealth correlation. The highest mean sharing frequencies, with over four meals in and out per week, were recorded by medium and better-off groups in LHG. This was more than double the level for poor groups, which recorded an average of only 1.5 meals in or out per week. Against a background of lower overall sharing, wealth differences were less marked in GUR and GBW (overall around 1-2 meals per week; in and out). The disparity is consistent with the greater divide between poor and better-off groups in LHG (Chapter 4). Reasons for the indeterminate outcome in MAD, where most sharing occurred in the medium wealth group (> 2.5 meals per week, in and out), are less clear.

In Gurulupitigama medium and better-off families also provided meals to hired labour during harvest time. Similar behaviour observed in the other villages was not captured by this survey.

Analysis of meal sharing behaviour revealed that the great majority of such exchanges take place between immediate family groups (Figure 6.3). Marginal differences were recorded between the mean number of incoming and outgoing meals in most cases, although a number of older dependents and households affected by illness, did benefit on a less reciprocal basis.

Rather than complete meals, sharing usually involves the exchange of special dishes incorporating meat fish or vegetables. Such dishes take a longer time to prepare and / or are relatively costly and therefore less frequently consumed. Together these results indicate that sharing is as much a social bonding and labour saving phenomena as a coping strategy. There appear to be two reasons for the lower participation rates of the poor. Firstly, the poor appeared less well connected with close kin families, particularly in LHG, where their marginalisation was most extreme (Chapter 4). This therefore becomes an important dimension of their poverty. Secondly, as most subsistence fishing is undertaken by poorer households (Chapter 5), indirect benefits are likely to be outweighed by direct benefits, e.g. direct household consumption.

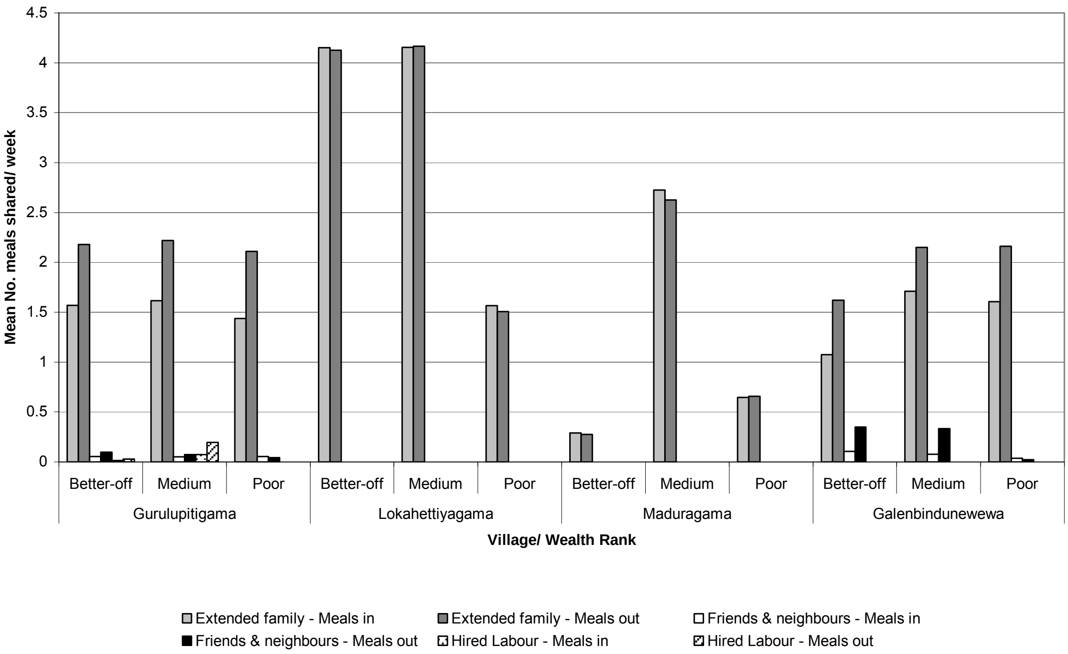


Figure 6.3 Mean number of shared household meals per week by village and wealth rank, Nov 00 - Dec 01

6.2.3 Intra-household equity

Frequencies of 'non-consumption' for different sources of protein were assessed to give some indication of intra-household equity. Gender-equity was of particular concern, i.e. having established that women play no active role in the fishery; did they also consume less food and if so was this self-imposed for cultural reasons, reasons of personal preference (avoidance) or were they more actively discriminated against, i.e. who controls food allocation?

Respondents were asked who in their household had not consumed any of the fish / fish substitutes purchased during the week prior to the interview, along with the reasons for non-consumption. Only households recording purchase of a particular item during any given week were included in the assessment. Results were cross-tabulated against three background variables: relational category (i.e. male and female adults or children), household wealth rank and reason for non-consumption (Figure 6.4). The number of 'non-consuming' individuals was then expressed as a percentage, with the total cumulative household occupancy for the entire population as the denominator. The focus on split-consumption households and failure to collect occupancy data disaggregated by relational category means that results are indicative of relative rather than absolute differences between the various sub-groups.

Children recorded the widest range and highest total 'non-consumption' over all food groups (seven food groups and 25.2% of cumulative occupancy (CO) respectively), followed by adult females (four groups and 19.6% CO) and finally adult males (two groups and 6% CO). A fourth adult group undifferentiated by gender accounted for 6.6% of cumulative occupancy (one food group).

However, compared to adults, child non-consumption levels were relatively low (<3% CO) for most food groups with the exception of wild game (11.4% CO) and fresh inland fish (5.3% CO). Many parents avoided feeding young children small tilapias because of their high bone content. Game is often consumed as an accompaniment to alcohol by adult males, particularly within the poorest wealth group. Consequently, social exclusion was cited as an important reason for non-consumption of wild game by poorer adult females and children. Taste preference was cited as the principle reason for non-consumption of wild game by medium and better-off females and children, as well as for non-consumption of other farmed meat products by all wealth ranks. Adult males rarely rejected any of the animal meat products acquired by a household.

Non consumption rates for ‘eggs and dairy products’ were the highest for any food group (24.6% CO for all groups), with ‘insufficient quantity’ cited as the principle reason, particularly by the poor. Many of these products, in particular dried milk are relatively costly and available supplies are selectively fed to the young and elderly members of poorer households. Both adult males and females show restraint in this respect; but most especially females. Amongst adults, only better-off females recorded moderately high non-consumption levels for fresh inland fish (1.4% CO) citing taste preferences, while there was negligible rejection of dried marine or inland forms by any group, i.e. these are staple accompaniments with most meals (section 6.2.4).

Anecdotal evidence suggested that elder members of better-off households were most likely to reject fish and meat consumption on the grounds of religious and cultural taboos. However, little evidence was found for this in the current survey. One reason for this was that many of such households abandon consumption entirely and therefore fell out-with the scope of this analysis.

In summary, results indicated relatively high levels of intra-household consumption equity, though children and adult female members of poorer households were likely to consume less dairy and animal protein than adult males. Consumption patterns for inland fish indicated increased production can be expected to bring widespread direct nutritional benefits to all but the very young, particularly if smaller tilapia production is the norm. This is significant given the high levels of stunting and wasting amongst rural children (Chapter 1). Conversely poorer women are likely to benefit as much as poorer males and more than better-off women.

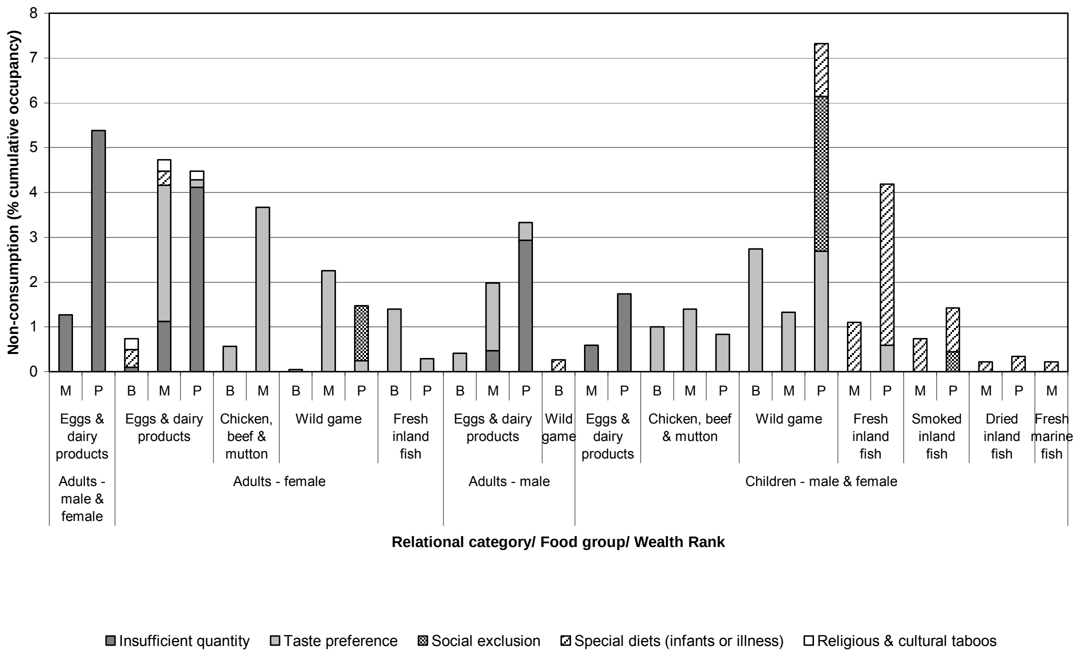
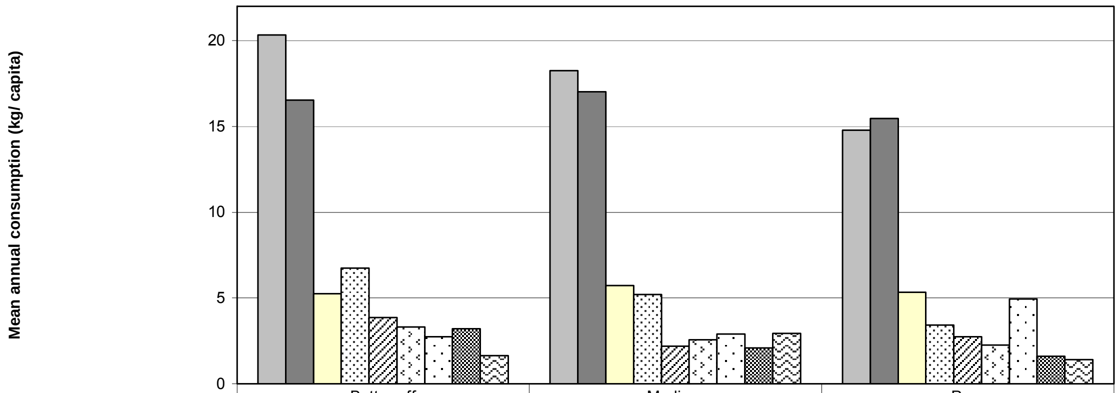


Figure 6.4 Cumulative incidence of intra-household protein 'non-consumption' by food type and wealth rank in four low caste villages Nov 00 - Dec 01

6.2.4 *Per capita* consumption of inland fish and its substitutes

Fresh inland fish and dried marine fish were the most important animal protein sources for all wealth groups (Figure 6.5). This is of particular significance, given they are high quality foods in terms of essential fatty acids. Annual *per capita* fish consumption (inclusive of fresh and dried, marine and inland fish) totalled; 28.2, 27.7 and 22.6kg for all better-off, medium and poor wealth households respectively (representing an overall weighted average of 26kg). These values can be contrasted with published mean national fish consumption levels (all forms) ranging from 10.6 - 18.6 kg $caput^{-1}$ yr^{-1} (47 - 50% of total animal and dairy protein (ADP), or 12 - 13% of total protein) over the previous two decades (NARA 1998). Fresh inland fish contributed between 15.5 - 17.5kg of the village totals (i.e. 60% - 67% of ADP) underscoring the sector's contribution to basic rural food security. These levels were comparable to those for commercially sourced vegetables; results presented here exclude on-farm vegetable production.

Although the absolute quantities of dried marine fish were relatively modest compared to inland fish and vegetables, it was consumed almost as frequently as vegetables for which it is an interchangeable accompaniment (Figure 6.6). This factor, along with its concentrated form and good access to all members of the household (section 6.2.3), makes dried fish quantitatively as significant as inland fish in terms of protein consumption when both are considered on a dry-weight basis.



	Better-off	Medium	Poor
Vegetables	20.3	18.2	14.8
Fresh inland fish	16.5	17.0	15.5
Wild harvested plants	5.2	5.7	5.3
Dried marine fish	6.7	5.2	3.4
Eggs & dairy products	3.9	2.2	2.7
Fresh marine fish	3.3	2.6	2.3
Wild game	2.7	2.9	4.9
Chicken, beef & mutton	3.2	2.1	1.6
Dried inland fish	1.6	2.9	1.4

Wealth Rank

Figure 6.5 Mean annual *per capita* consumption of inland fish and its substitutes by wealth rank in four low-caste villages, Dec 00 - Nov 01

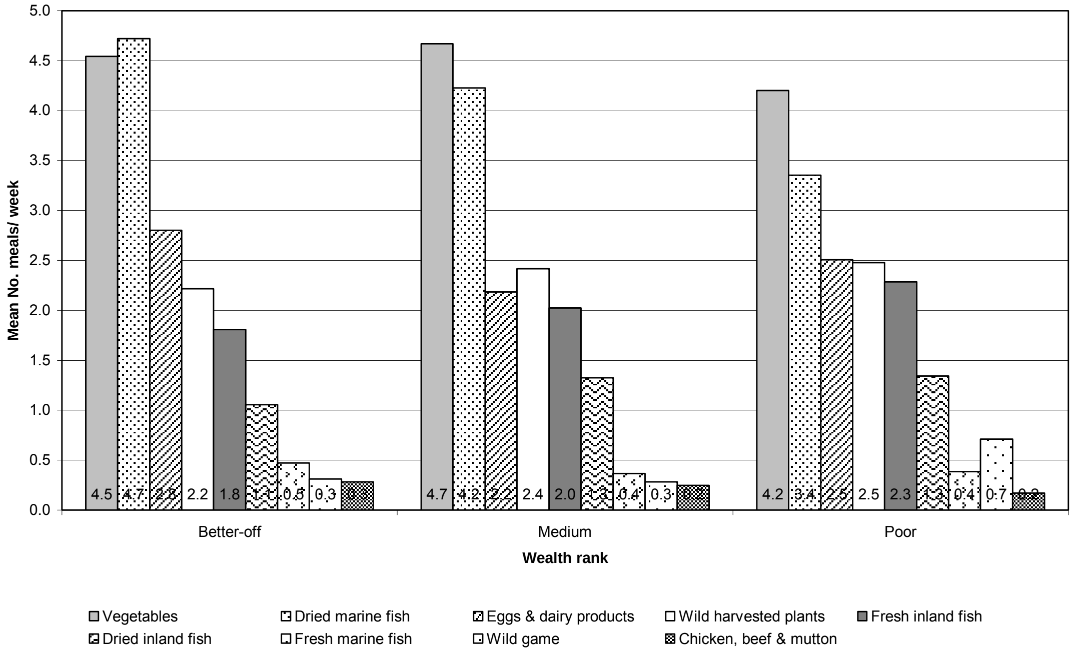


Figure 6.6 Mean weekly meal frequency for inland fish and its substitutes by wealth rank in four low-caste villages, Dec 00 - Nov 01 (data values shown)

Aggregate consumption for all the food categories considered here correlates closely with wealth status; better-off medium and poor individuals consumed 63.6, 58.9 and 51.9 kg yr^{-1} respectively. The poor do however consume larger amounts of wild-harvested products, particularly game (4.9 kg *caput*$^{-1}$ yr^{-1}) which is consumed at almost twice the volume and frequency (on average once per month), of other wealth groups. Poor and medium wealth households also consume inland fish more frequently than better-off groups (on average 2.3, 2 and 1.3 meals per week respectively) although in smaller quantities.

An unexpected finding related to the consumption of wild-harvested plants by all wealth groups (ranging from 5kg – 5.7 kg *caput*$^{-1}$ yr^{-1} with meal frequencies of 2.2 – 2.5 per week). These plants provide so-called 'green-leaves' that are eaten fresh as a salad accompaniment with most Sri Lankan meals. However, as they (1) typically have water contents of 85% or more by weight (Rajapaksha 1998) and are (2) consumed in small but regular quantities, their nutritional value lies mainly in the supplementary provision of vitamins and other micro-nutrients. The consumption of a large number of varieties in fresh form by most households is likely to ensure much of the requirement of the human body for these nutrients. They also have less potential for contamination by agro-chemicals compared to commercially grown crops. Many are used for medicinal purposes, both for humans and livestock.

Many of the varieties recorded grow around the littoral areas of village tanks and paddy fields where they represent an important additional source of aquatic production. Common aquatic varieties include: *manil* (*Nymphacea lotus*), *nelum* (*Nelumbium nuciserun*) and *kohila* tubers, leaves and seeds (*Lasia spinosa*), *sarana* stems and leaves, *mukunuwenna* (*Alternanthera sessilis*), *neeramuliya* (*Asteracantha longifolia*), and *keketiya* (*Aponogeton crispus*). Varieties which grow mainly in home-garden or forest areas include *gotu kola* (*Centella asiatica*) *kirianguna* (*Drega volubilis*) and *thalkola* (*Ipomea obscura*). *Thalkola* stems are also used for weaving. Together these plants provide a rich source of calcium, phosphorous, iron, thiamine, vitamin C. riboflavin and niacin (Rajapaksha 1998). The vitamin content appears most significant, as the first three minerals are also abundant in many fish products.

6.2.5 Yields and consumption of inland fish from different production sources and marketing channels

Sources of inland fish were placed into three categories (1) village tanks where stocking interventions had taken place (2) 'Other' village tanks and (3) major perennial reservoirs.

Roughly one third of total annual consumption (29.5%), originated from the two village tank categories. This included 12% from stocked tanks, rising to19.1% excluding GUR (i.e. which was not stocked in the phase 2 trials). Of the former total, 28.1% consisted of subsistence production with 23.8 % self-caught and 3.8% 'gifted-in' for household consumption (Figure 6.7). Only 1.9% was obtained through commercial channels and most of this production came from larger lower-watershed tanks in GUR and Pahala Giribawa (PGB) below MAD. These figures underscore just how significant production from local village tanks already is to rural livelihoods although they are largely excluded from national statistics which consider only commercial production from larger medium and major irrigation systems. As most of the intervention tanks were depleted of resident stocks prior to the study, the results also demonstrate the potential for simple stocking enhancements.

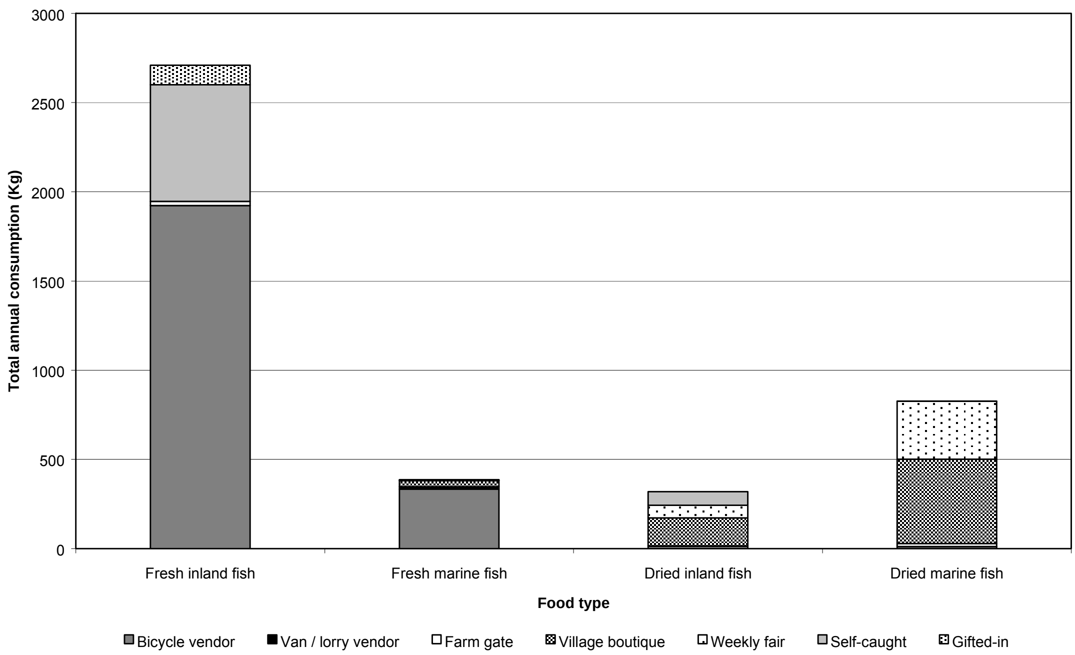
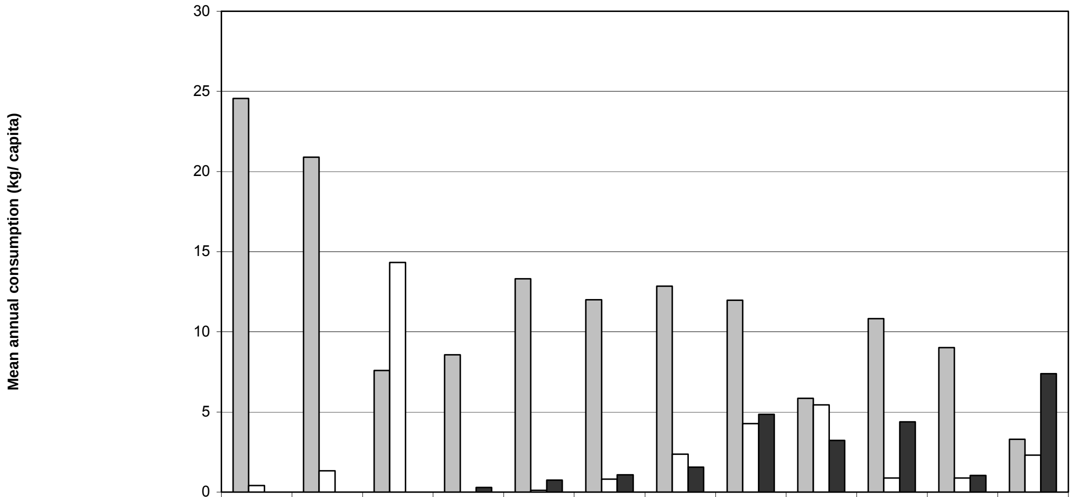


Figure 6.7 Total annual consumption of fresh and dried fish products by 41 households in four low cast villages by marketing channel, Dec 00 – Nov 01

Consumption from the different sources once again showed a close correlation with wealth status (Figure 6.8). Better-off groups consumed mainly commercial produce from perennial reservoirs, while poor groups relied more heavily on subsistence production from the other two local sources.



	Gurulupitigama			Lokahettiyagama			Maduragama			Galenbindunewewa		
	Better-off	Medium	Poor	Better-off	Medium	Poor	Better-off	Medium	Poor	Better-off	Medium	Poor
Major irrigation system	24.6	20.9	7.6	8.6	13.3	12.0	12.8	12.0	5.9	10.8	9.0	3.3
Other village tank	0.4	1.3	14.3		0.1	0.8	2.4	4.3	5.4	0.9	0.9	2.3
Stocked village tank				0.3	0.7	1.1	1.6	4.8	3.2	4.4	1.0	7.4

Village/ Wealth rank

Figure 6.8 Mean annual *per capita* consumption of inland fish by production source, village location and wealth rank, Dec 00 - Nov 01

This is clearly demonstrated in GUR, the control community, where combined seasonal tank production contributed 23.2% of total fresh inland fish consumed by all wealth groups. This ranged from 1.6% to 65.3% of consumption for better-off and poor households respectively. Some 18.3% of the latter figure came from their own lower-watershed village tank and 47% from other, mostly large drainage tanks, situated below the major Rajangane Reservoir.

Similar trends were evident in the stocked village tanks, where production contributed 5.7%, 18.4% and 32% of total annual household consumption and 7.9%, 22% and 56.9% of 'poor' household consumption in LHG, MAD and GBW respectively. The lower results in LHG and MAD must be set against a background of greater relative water scarcity in these upper-watershed areas and greater availability of commercial fish production as a result of their proximity to Rajangane Reservoir.

In absolute terms, stocking related *per capita* consumption (Figure 6.8), ranged from a minimum of 0.3 kg yr^{-1} (LHG Better-off) to a maximum of 7.4 kg yr^{-1} (GBW Poor). The high relative and absolute contribution in GBW is attributable to the small size of the community (25 households) relative to the size of their stocked tank (8.2 ha). This resource 'richness' is due the relatively recent settlement of this remote area (Chapter 4). Conversely the same remoteness meant that GBW also had poorest access to commercial sources of fish (section 6.2.7).

MAD with 51 households, but only 5.4 ha combined tank surface area (both stocked tanks) produced twice the GBW yield (see below), but recorded lower *per capita* consumption levels because of this ratio. The LHG intervention (47 households and 13.6 ha surface area) underperformed dramatically. However fishing-related conflicts in LHG probably resulted in significant under-reporting in this survey, as they had in the key informant techniques reported in Chapter 5.

In GBW better-off households lobbied for adherence to traditional collective harvesting practices in large part to maintain their position in the social hierarchy (Chapter 5). Consequently, this group received a larger proportion of the catch than in any of the other villages. Conversely, the superior performance in MAD, where emphasis was on staggered harvesting, can be attributed to strong pre-existing social cohesion within the village (Chapter 4). This is reflected in the equitable distribution of production between wealth classes (Figure 6.8).

6.2.6 Area yield estimates

The *per capita* results presented above correspond to total yields of 49.4, 342 and 695 ha^{-1} yr^{-1} from stocked tanks in LHG, GBW and MAD respectively. Values are extrapolated from mean annual village population and resource extent (50% full supply level (FSL) surface area of stocked tanks). Again, the MAD value is based on the combined yield and area of both stocked village tanks; LUN and KRB. These estimates are compared with the direct observation survey results reported in Chapter 5 and PIM results presented below in section 6.4.

6.2.7 Retail price and seasonal availability of commercial production

More than two thirds of fresh fish consumed in rural villages consists of commercial production delivered to the door step by bicycle vendors (Murray 2004a, Plates 6.1 A and B). Such deliveries accounted for 71.2% and 86.3% of total annual inland and marine fish consumption respectively in all four villages. An additional 0.7% of inland fish originated from farm-gate sales. The latter total consisted mainly of unsold stocks consumed (at cost) by bicycle vendors living in LHG and MAD. Finally, direct sales of discounted 'tank fish' by local subsistence fishermen contributed an additional 0.5% of total consumption.

A **B**

Plates 6.1 A and B: Bicycle vendors selling fish from major reservoirs in project villages, Nov 2000; (A) carp steaks from a fish too large to be sold whole (B) high value snakehead.

As previously indicated, the significance of commercial production varied widely between villages. Bicycle vendors supply more of the fish consumed in well connected villages (>75% in GUR and LHG) compared to the more remote (60% or less in MAD and GBW)

In order to assess the seasonal trends in the availability of commercial production, participants were asked to recall (1) the number of days when vendors visited the village during the week prior to interview and (2) the number of vendors visiting the village on each occasion. The mean number of inland and marine fish bicycle vendor visits per week to each village was calculated from these responses, (Figure 6.9 and Figure 6.10). Mean retail prices charged by the same vendors for fresh inland fish are also shown over the same period (Figure 6.11).

Results show that the commercial availability of inland fish fell dramatically between March and June and to a lesser extent during August and September. The first crash was a result of adverse seasonal fishing conditions exacerbated by the temporary imposition of fishing restrictions on two nearby commercial fisheries supplying much of the villages needs (Murray 2004a). The number of visits fell progressively from 9-35/wk to 0-10/wk amongst the different villages. The fall in supply coincided with a period of peak demand for April New Year celebrations causing the mean retail price of small tilapias to reach an extreme annual high of Rs 60/kg. The second decline was associated with the usual seasonal fall in commercial production during the dry season (see seasonal calendar - Appendix 27).

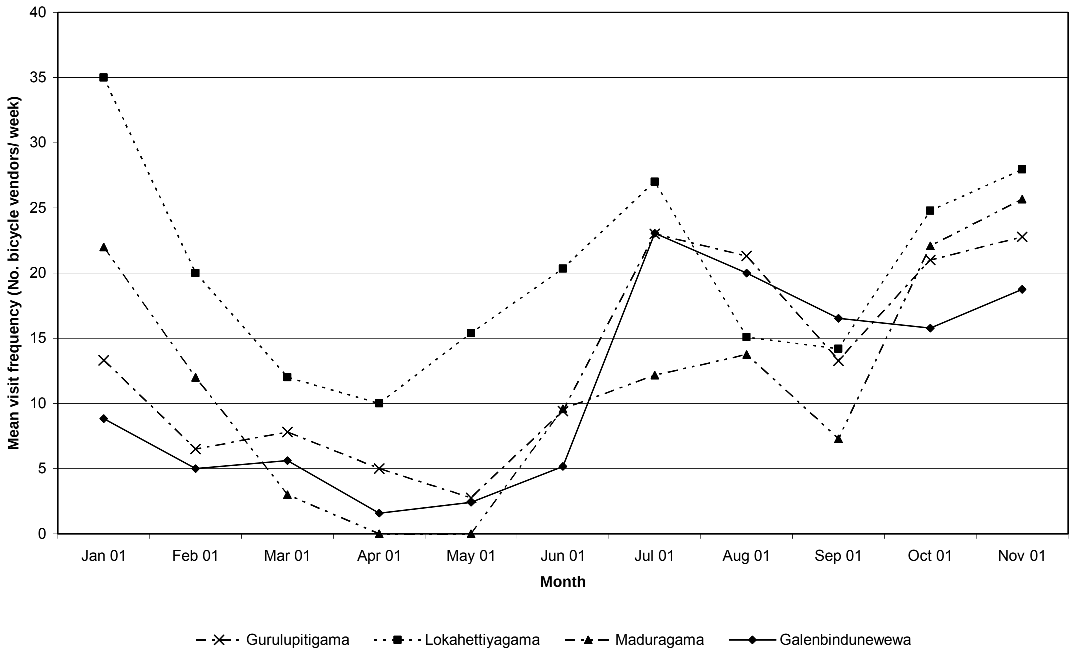


Figure 6.9 Mean number of inland-fish bicycle vendors per week, visiting four low-caste villages, Jan 00 - Nov 01

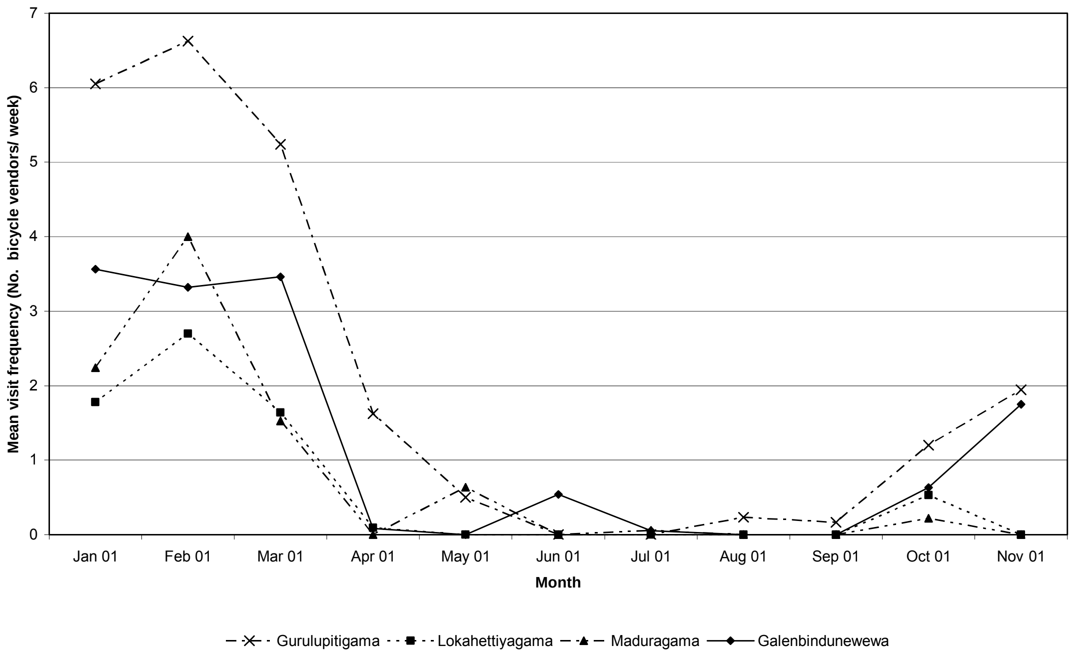


Figure 6.10 Mean number of marine-fish bicycle vendors per week, visiting four low-caste villages, Jan 00 - Nov 01

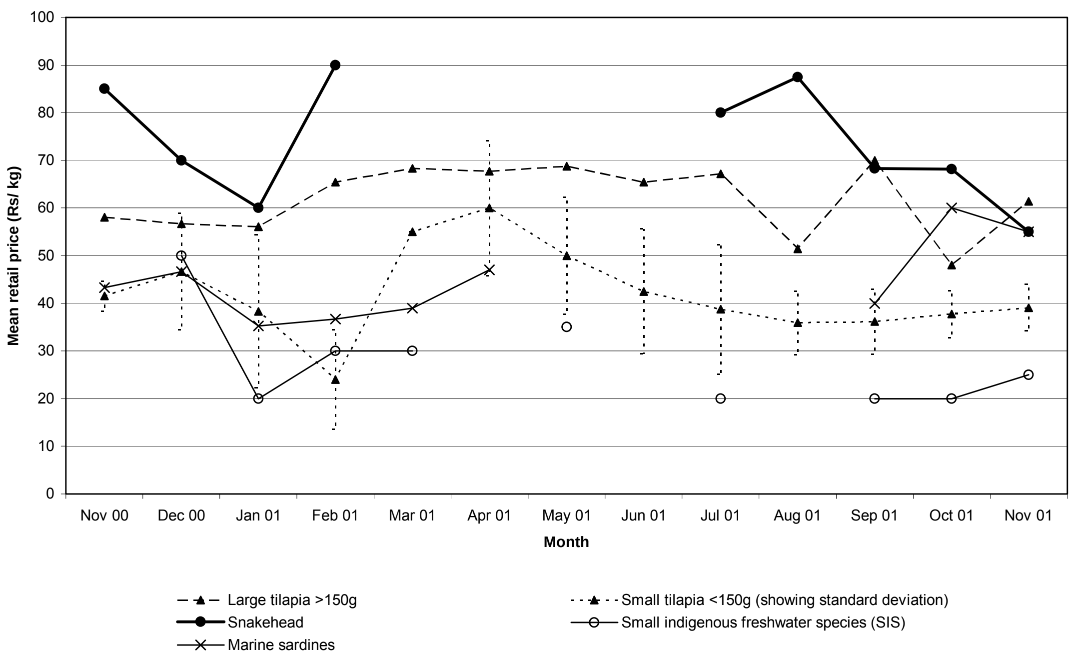


Figure 6.11 Mean monthly retail price of selected fresh inland and marine fish varieties sold by bicycle vendors in four low-caste villages, Nov 00 - Nov 01 (standard deviation bars shown for small tilapia)

All but one professional bicycle vendors from the research villages (3 in LHG and 2 in MAD), were amongst the first of the 'Rajangane vendors' to lose their livelihood during this time. The exceptional vendor was longest established in the business having reliably dealt with the same fishermen for over eight years. The deficit in fish availability was partially offset by increased numbers of marine fish vendors visiting the villages during January to March (2-7 visits/wk), but thereafter, marine supplies also decreased and much of the limited remaining inland production appeared to be selectively used to meet demand in more accessible rural towns and villages (Murray 2004a). This meant that negligible quantities of marine fish reached any of the research villages between April and September.

The number of inland fish vendor visits increased again following the collapse of the fishing restrictions around June combined with increasing CPUE as water levels receded. Thereafter, levels declined to 8-17 visits/wk in September as yields fell with the progression of the dry season, rising again in October with the onset of the rains.

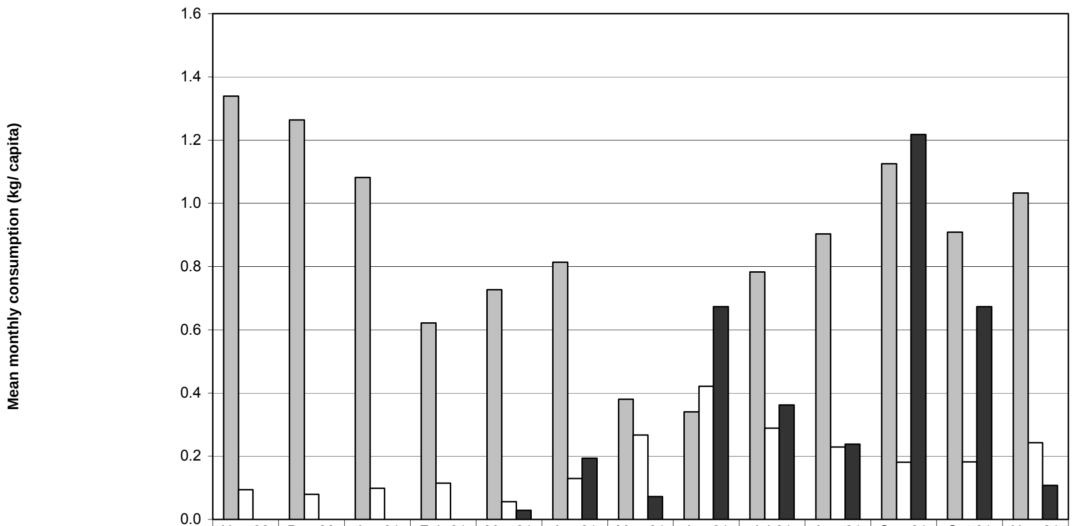
Seasonal trends in retail prices for fresh fish (Figure 6.11) confirmed that fish-size was a key factor (Murray 2004a). Respondents were asked to recall the number as well as weight of fish in each transaction from which the following mean size ranges were interpolated (standard deviations in brackets): SIS 39g (29 - 61g), small tilapia 106g (85 - 141g), large tilapia 236g (184 - 329g), snakehead 611g (433 - 611g). Snakehead was the most expensive regularly consumed inland species with prices ranging from Rs 60-90/kg, while small indigenous species were least expensive ranging from Rs 20-50/kg. For much of the year tilapia were priced within two 'small' and 'large' size categories but during periods of relative abundance vendors also created a medium category of intermediate size and price (data not shown). Price differentials decreased during periods of scarcity most notably in April. Prices for sardines, the cheapest marine fish and closest substitute for small tilapia, are also shown. The largest and most expensive marine varieties (up to Rs 200/kg) available in the villages were primarily supplied by a lorry-vendor which visited the two most accessible villages; LHG and GUR (Figure 6.7).

The small quantities of commercial production originating from village tanks retailed for a lower price than the same varieties harvested from major reservoirs. Both snakehead and SIS averaged 90% of major reservoir prices while small tilapia (<150g) averaged only 74.5% (data not shown).

6.2.8 Seasonal *per capita* consumption of inland fish from stocked tanks

In terms of the vulnerability context, the success of stocking interventions must also be judged on their seasonal contribution to livelihood security. This is of particular importance to poorer households who tended to be more reliant on the immediate local natural resource base (Chapter 4).

Stocking took place between October and November 2000 and the first harvest (in GBW) commenced just 5 months later in March 2001 (Figure 6.12 and Figure 6.13). Thereafter, there were three distinct consumption peaks corresponding with production trends described in Chapter 5, which I will briefly summarise. The smallest; the result of ‘spill-fishing’ in April only took place in GBW as spill events were too minor in the other intervention tanks (Figure 6.13). Thereafter, different harvesting strategies were adopted in each village. Attempts were made to ban staggered harvesting by poorer households using hook and line in both LHG and GBW. Similar proscription in MAD was revised with majority support, after a community meeting to review the research process at the end of May (Chapter 3). The subsequent resumption of hook and line fishing resulted in the selective removal of larger fish. In MAD this was responsible for the second production peak which occurred in June.



	Nov 00	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01
Major irrigation system	1.34	1.26	1.08	0.62	0.73	0.81	0.38	0.34	0.78	0.90	1.13	0.91	1.03
Other village tank	0.09	0.08	0.10	0.11	0.06	0.13	0.27	0.42	0.29	0.23	0.18	0.18	0.24
Stocked village tank					0.03	0.19	0.07	0.67	0.36	0.24	1.22	0.67	0.11

Month

Figure 6.12 Mean monthly *per capita* consumption of inland fish by production source in three low-caste villages post-stocking, Nov 00 - Nov 01

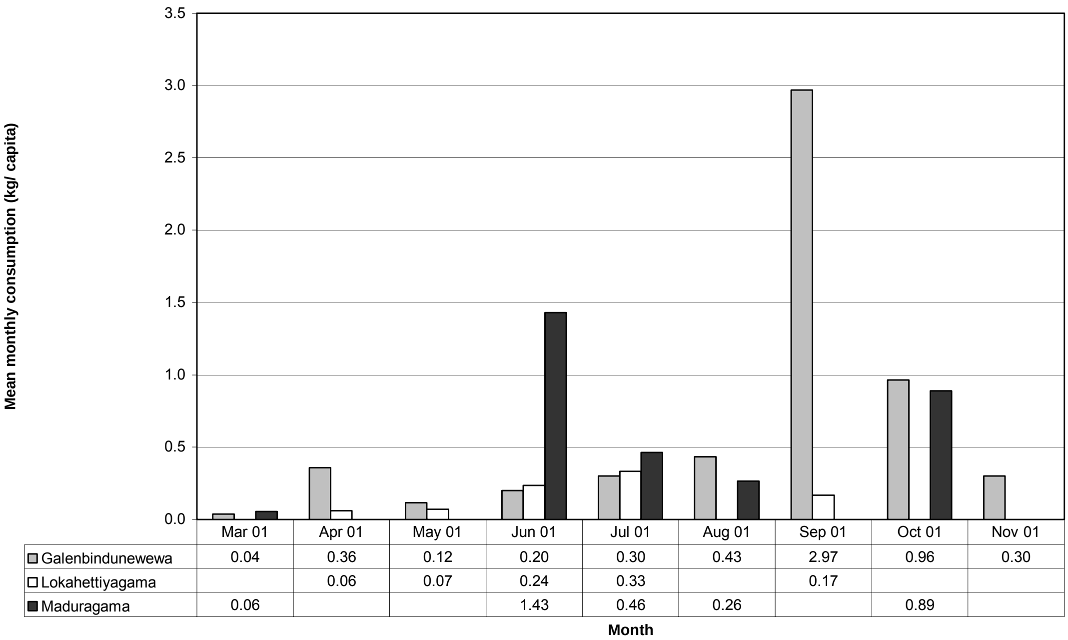


Figure 6.13 Mean monthly *per capita* consumption of fresh fish from stocked tanks in three low-caste villages, Nov 00 - Nov 01

The dates of collective harvest episodes ranged from late July (LHG) to early October (KBW). Yields associated with these events were erratic due to the interplay of management factors and tank physical characteristics. Smaller tanks such as LUN and KBW (in MAD village) with correspondingly low carrying capacities had much greater yield potentials under staggered rather than single collective harvest regimes. In this case collective harvests (which were staged as late as possible in the season, i.e. November to October) finally represented only a modest end of season production bonus despite *a priori* expectations. By contrast, the early harvest in LHG was prompted by an increase in unregulated fishing activity rather that any strategic management decision. This was a significant factor in the village's poor overall yield outcome. Whilst GBW proved a more cohesive community than LHG, here too collective fishing was staged prematurely, this time at the end of August. The event was prompted by the unilateral action of a few disgruntled poorer households who invited neighbouring villagers to fish freely. This was presented as a *fait acomplis* to the wider community including village institutional officials responsible for their earlier exclusion (Chapter 5). Nevertheless, the relatively large size of the tank together with some prior restriction on staggered harvesting effort meant this one event was responsible for the single largest monthly production peak (September 01)

The overall importance of production from stocked tanks relative to other sources in the three intervention villages during the second half of the year is clearly illustrated in Figure 6.12. Between April 01 and Nov 01 'stocked' tanks provided nearly one third or 3.5kg of mean total *per capita* fresh inland fish consumption.

6.2.9 Seasonal production from 'other' village tanks and access arrangements

The design of this survey also made it possible to assess the relative contribution from 'other' village tanks, i.e. out-with the *purana* complex or from un-stocked tanks within to *per capita* consumption and basic household food security.

A major determinant of the marked variation observed between the four communities (Figure 6.15), lay with the variable access arrangement accorded to different types of village tanks. Open access regimes prevailed for many of (1) the largest and (2) remotest tanks. Conversely, CPR regimes occurred where (3) the resident community accorded low priority to fishing and tolerated limited external participation (4) close kinship linkages existed between users in the local community and (5) reciprocal access arrangements for collective fishing were in existence.

GUR and MAD villagers recorded the greatest reliance on these external sources consuming on average 6.7 and 5.2 kg *caput*$^{-1}$ yr^{-1} (Dec 01 – Nov 01) respectively. This contrasted with levels of 1.8 and 0.31kg in GBW and LHG. The likely reasons for these disparities along with examples of the access conditions given above are presented in the following sections.

'External' production expressed as a percentage of total consumption (corrected for differences in wealth group sample size), also showed systematic variation between village and wealth status (Figure 6.14). Poor wealth groups were again the largest consumers of this source of fish in all villages, i.e. their subsistence strategies frequently extend beyond village boundaries. The differences between different wealth groups were least marked in MAD, the most socially cohesive village.

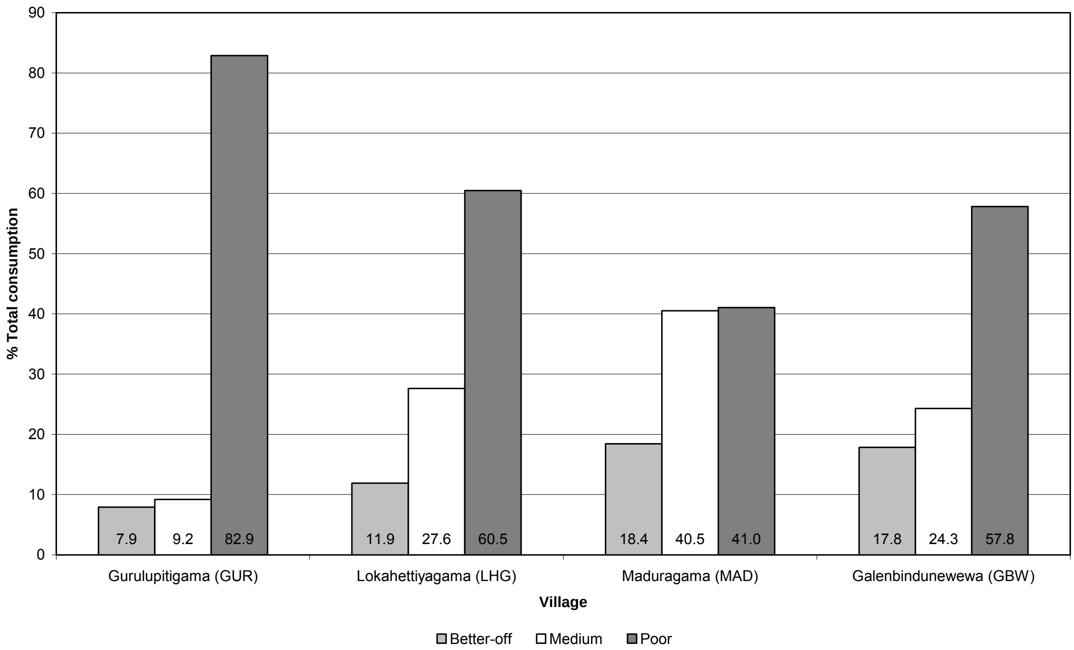
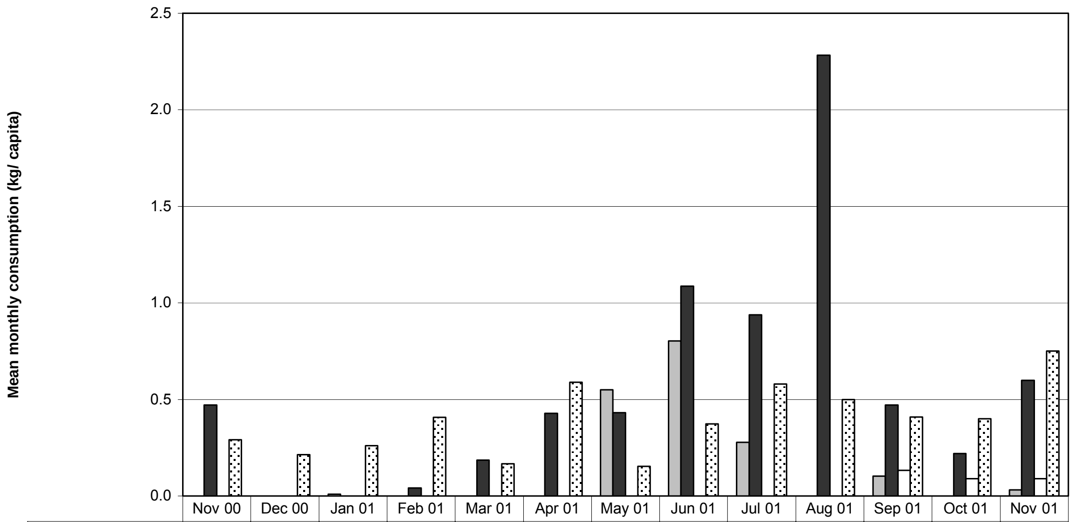


Figure 6.14 Percentage of total annual production from 'other' village tanks consumed by households belonging to different wealth groups in four low-caste villages, Nov 00 - Nov 01

Seasonal tank production in the ‘control’ village, GUR, came from three main sources: GUR tank itself (22.2ha), Pahala Wembuwa (PBW: 4.1ha) the larger of two additional highly-seasonal tanks within the GUR PC, and Madawalagame (MDW: 27.9ha) a semi-seasonal tank belonging to an affluent upper caste community who tolerated limited access by members of the neighbouring GUR community (Figure 6.16). Over the entire survey period, 62% of seasonal tank production came from within the village (40% from GUR and 37.8% from PBW), while 22% came from outside (mostly MDW). Only 3.2% of this production was sold commercially by a group of local youth regularly fishing in GUR from home made floats using gill nets.

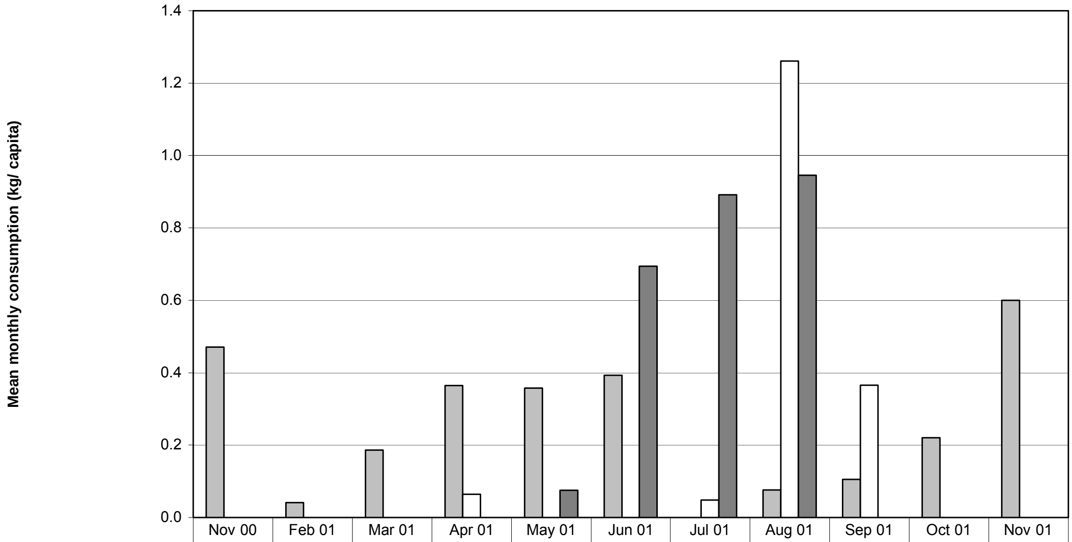
Averaged over the whole community, these consumption levels correspond to annual yields of 30.3, 51.2 and 309.5 kg ha^{-1} yr^{-1} in MDW, GUR and PWB respectively. Despite its small size PBW, made a significant contribution to local consumption between the months of May and August when yield levels from the two larger perennial tanks were in transition. These results underscore findings presented in Chapter 5; that seasonal tanks with higher CPUE can produce higher yields than larger perennial tanks with higher absolute levels of standing stocks, given a favourable sequence of above and below average rainfall years.



	Nov 00	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01
Galenbindunewewa			0.01				0.55	0.80	0.28		0.10		0.03
Gurulupitigama	0.47			0.04	0.19	0.43	0.43	1.09	0.94	2.28	0.47	0.22	0.60
Lokahettiyagama											0.13	0.09	0.09
Maduragama	0.29	0.21	0.26	0.41	0.17	0.59	0.15	0.37	0.58	0.50	0.41	0.40	0.75

Month

Figure 6.15 Mean monthly *per capita* consumption of inland fish from 'other' village tanks in four low-caste villages, Nov 00 - Nov 01



	Nov 00	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01
Gurulupitigama	0.47	0.04	0.19	0.36	0.36	0.39		0.08	0.11	0.22	0.60
Madawalagame				0.06			0.05	1.26	0.37		
Pahala Wembuwewa					0.08	0.69	0.89	0.95			

Month

Figure 6.16 Mean monthly *per capita* consumption in Gurulupitigama from different village tanks, Nov 00 – Nov 01

Participants in MAD, the lowest caste village, consumed slightly lower quantities of fish from ‘other’ tanks (72% of the GUR total), but maintained much more constant consumption levels throughout the entire survey period despite their upper-watershed position (Figure 6.15). This feat was achieved through exploitation of a substantial number and physical range of tanks within a wide, 6-7km radius, of the village. Fish consumption from twelve different tanks was recorded over the course of the year, inclusive of three tanks within the MAD *purana* complex, of which two were stocked. Over half the total production from 'other' tanks (3.27 kg *caput*$^{-1}$ yr^{-1}) came from a large but very shallow tank; Pahala Giribawa (PGB: 89ha) at the bottom of the MAD watershed. This tank was effectively open access to a large and heterogeneous population located around it, for all functions except irrigation. It became a particularly important resource in the dry season when many smaller village tanks were reduced to muddy pools. A more detailed case study of fishing mobility in MAD is presented in the next section.

Villagers in GBW and LHG harvested relatively small amounts of fish from external tanks. In GBW, this was due to lower tank density around the village and the relative abundance of the resource within the village. Over the year, villagers caught fish from five external tanks within an 8km radius. Over three quarters of this production (1.4 kg *caput*$^{-1}$ yr^{-1}) came from just one tank, Kahatagahawewa (KHG: 2ha) located less than 1km from their village on the periphery of an adjoining PC. In this instance GBW villagers shared kinship bonds with the owners of the tank and enjoyed assured access as long as they respected bathing rights, i.e. they used only hook and line to fish. This tank provided an important source of fish for poorer households between May to June prior to the onset of staggered harvesting in GBW.

Several regular fishermen in GBW complained that reciprocal access arrangements with a neighbouring village / tank, Ralapanawe (RLP: 12.5ha), had been curtailed by the intervention. Previously villagers from both communities participated informally in each others collective harvest; normally this would happen on the second or third days of the event. As well as being an important social occasion, this also allowed pooling of gears and manpower making the fishing more efficient in these two relatively large tanks. Ultimately, the impasse between regular subsistence fishermen in GBW and influential villagers who wished to proscribe fishing resulted in the chaotic collective fishing event described above and more fully in Chapter 5.

In LHG external fishing was recorded from only one tank, Pahala Giribawa (described above), during the months after premature collective harvesting had curtailed yields in their own stocked tank (Sep 01 – Nov 01). Much of the fishing here was undertaken by groups of poorer youth for recreational reasons as well as providing food for the household. Conflicts with established village institutions, which tend to be mainly controlled by better-off households, persisted and they continued to act unilaterally despite attempts to encourage their participation in a fishing society. These problems were compounded by intra-household attitudes towards participation, i.e. many wives objected to their husbands continued participation in subsistence fishing because of its association with alcohol consumption and generally anti-social behaviour in this village. These difficulties meant that it was also very difficult to identify and monitor participants even within the longitudinal household survey framework. Consequently, catch data was also likely to have been under-reported in this and the other surveys (Chapter 5).

6.2.9.1 Fishing strategy and mobility in Maduragama village

In this section I present a case study which examines the strategies adopted by different groups of fishermen in MAD and how and why they are traded off. This includes the exploitation of tanks belonging to neighbouring villages and the importance of this activity relative to their own internal production. Maduragama was selected as one the villages where this form of fishing made the most significant contribution to the livelihoods of the poor. In addition to the two stocked tanks; LUN and KBW, Maduragama villagers also controlled fishing in a third tank Hangogamawewa (HNG – Chapter 4).

In September 2001 one of the most experienced and active fishermen in MAD; Sisira Kumar aged 38, was questioned with several other fishermen in attendance, about the fishing activity of himself and other villagers during the previous twelve months. This interview yielded the mobility map in Figure 6.17 and the associated information shown in Table 6.1. Sisira reported that of 17 tanks traditionally exploited by MAD villagers, only 13 had been fished over the intervention period, i.e. corresponding very closely with the longitudinal household survey findings presented above. He pointed out that fishing in larger distant tanks (>3km) normally exploited during they dry season, had all but ceased during the course of the intervention due to the increased availability of fish within the village. In other words CPUE was dramatically increased when travel times are also factored in as a component of the effort measure.

This point was re-iterated by several respondents in the PIM survey (Section 6.3), who commented that time and effort expended on accessing remoter tanks and those with more conflict prone access arrangements had decreased significantly during the second six months of the trials. Therefore despite the continued wide-ranging access by MAD fishermen, stocking interventions in LUN and KBW clearly increased self-reliance within the village and reduced the likelihood of inter-community conflicts.

The external tanks ranged from 1.7 to 96ha in area (FSL). Nine of the 13 were greater than 8ha suggesting that 'highly seasonal tanks' are less favoured or at least should be in close proximity to the village. The selection of the remaining tanks demonstrated trade-offs between ease of access and conflict mitigation. They included several very large, essentially open-access perennial lower-watershed tanks and a larger number of closer intermediate sized tanks, many in remote locations. Fishing in the 'base' tanks of neighbouring villages, e.g. LHG and IMK was infrequent and limited to a small number of individuals. Conflicts were also avoided by adhering to hook and line fishing during most of the year although this was also a pragmatic response to weed infestation in many smaller tanks. Specialist fishermen also targeted certain tanks, for example to fish for eels or turtles. One respondent from LHG reported that the tendency for gypsies to leave piles of turtle shells behind their camps had in the past earned them the nickname of the 'turtle eaters'. Turtles were unpopular with most consumers. Consequently, their capture was tolerated in two tanks where local fishermen discouraged the capture of other fish species.

A total of 21 subsistence fishermen were identified who regularly fished in both local and external tanks. Twelve came from poor households and 9 from medium wealth households. An additional 5 villagers fished regularly, but only in the local MAD tanks, i.e. almost half the village households were involved in some form of regular fishing activity. Interestingly the 'additional 5 villagers' included the only two 'better-off' householders to participate in hook and line fishing along with 2 medium and 1 poorer household. Sisira indicated that several of these participants restricted their activity to KBW as LUN was more visible from the main road running through the village and they did not wish to be associated with regular fishing activity. He also suggested there was less potential for conflict with the priority bathing use in this tank. The ages of all the participants ranged from 13 – 42 including 5 teenagers. In

Murray (2004a) it was established that for cultural reasons male participation in the seasonal tank fishery is likely to decline with age. Therefore in this village, the participation of a large group of older respondents in external activity underscored the significance of fishing as a subsistence activity over and above its recreational component. Five of these 26 regular fishers; 2 poor, 2 medium and 1 better-off were randomly incorporated in the longitudinal household survey.

As indicated above, on several occasions villagers from MAD ‘poached’ fish from two of the ‘stocked’ tanks; LHG and Serugas (SER: 3.25ha) belonging to neighbouring communities. In the first instance the villagers took advantage of the disunity in LHG by participating both independently and informally with local youth. By contrast, low-level fishing was initially tolerated in SER. The tank is used primarily for irrigation with most of the adjacent inhabitants undertaking bathing activities in Ihala Maradankadawala (IMK: 18.1ha) the largest tank in this PC. The clear status of IMK as an important multiple-use common property resource together with it’s proximity to the community (unlike LHG), increased the observability and therefore reduced the incidence of poaching. The caste polarisation between IMK and neighbouring MAD, the most marked in the entire survey (Chapter 4), also meant that fishermen within the IMK community were unlikely to invite informal participation from the ‘gypsy’ village.

Villagers in MAD conceded external access to their largest tank; HNG on the periphery of the PC, but reserved the two most central ‘base’ tanks: LUN and KBW exclusively for themselves for all uses including fishing. Collective fishing in HNG attracted participation from three neighbouring communities including IMK. This was a pragmatic consensus in two respects; firstly the location of the tank made it difficult to protect and secondly it also increased tolerance to the wide-ranging ‘poaching’ activity of MAD fishermen in their neighbour’s tanks!

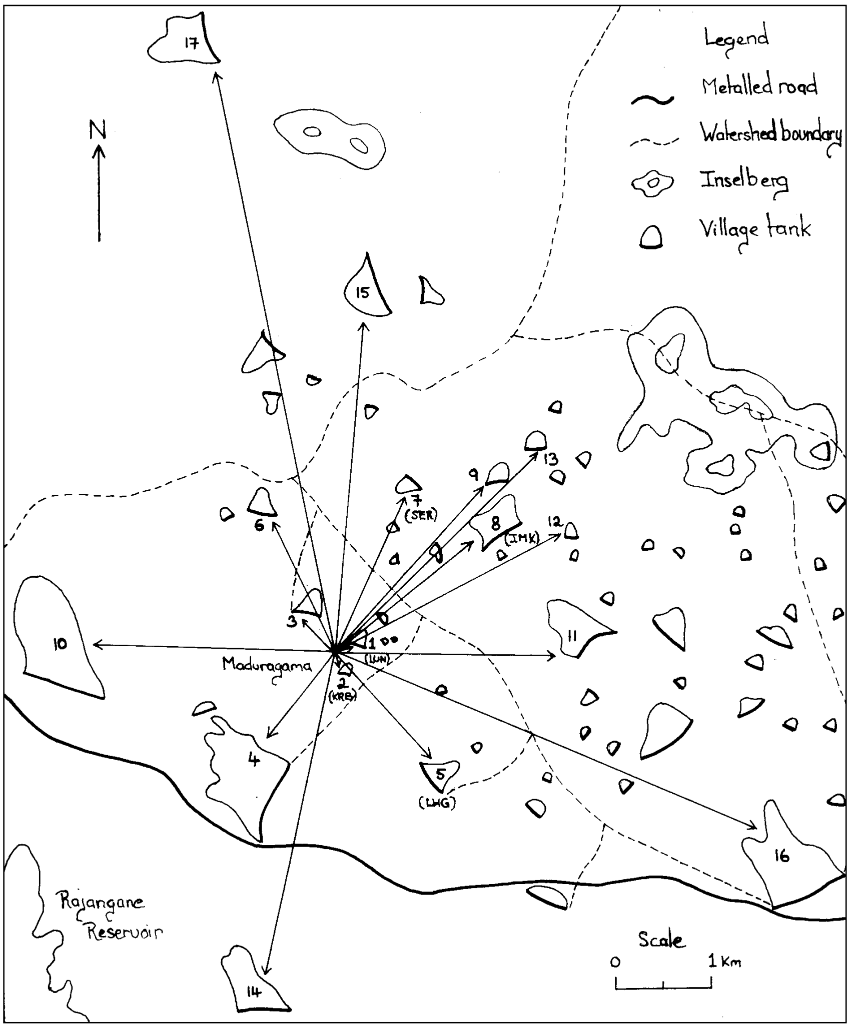


Figure 6.17 Mobility map showing tank sites fished by Maduragama villagers from Sep 00 to Sep 02 (numbers refer to tanks listed in Table 6.1)

Table 6.1 Recent fishing activity by Maduragama villagers in local (in bold) and external tanks from Sep 00 to Sep 01 (Source: focus group with MAD fishermen 7 Sep 01)

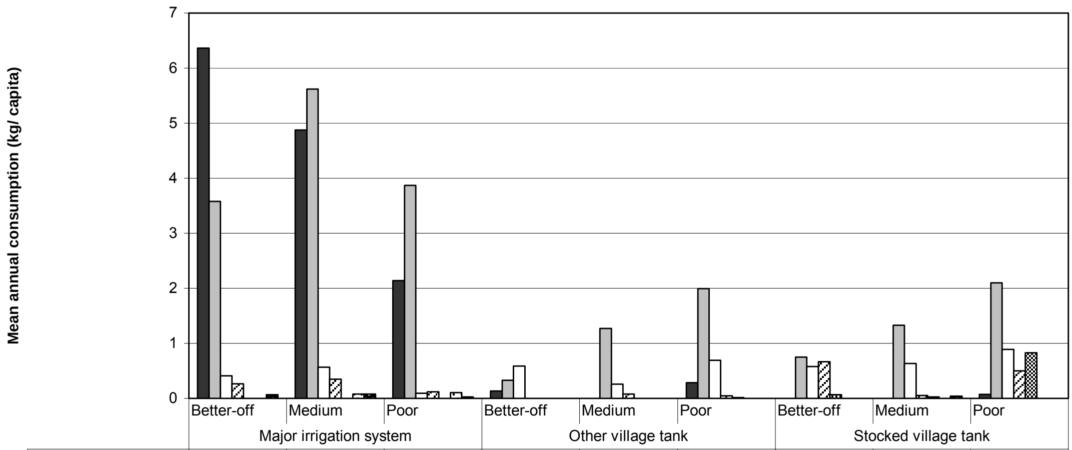
Map No. and name of tank (bold text = MAD tanks)		Km from MAD	Area at FSL (ha)	Last fished by villagers from MAD?	No's fishing	Fishing restrictions[1]
1	**Luna**	0	3.8	Daily last wk	5-11	HL only prior to CF
2	**Karamba**	0	1.9	Daily last wk	2-13	HL only prior to CF
3	**Hangogama**	0.5	3.5	CF last wk	30	HL, no CN/ GN prior to CF
4	Pahala Giribawa	1.3	89	Daily last wk	5-6	HL & CN (GN when full)
5	Lokahettiyagama	1.5	13.6	Jul-Aug	3	HL tolerated, no CN or GN
6	Yantampola	1.8	1.7	July	2	HL only
7	Serugas	2	3.3	July-Aug	3	HL only
8	IMK	2	18.1	Once last wk	2	HL only (no CF)
9	Welikandawa	2.3	2	July	4	Tortoises only
10	Ihala Giribawa	2.5	96	Weekly	2	HL & CN only
11	Werwanawetiya	2.5	8.1	July-Aug	4	HL only
12	Mahagalketiyawa	2.8	2	Pre-stocking	4	Turtles only
13	Medibegama	3	2	August	4	Turtles only
14	Weerapokuna	3.5	27	Pre-stocking	3	HL only
15	Mahagampola	3.8	11.5	Pre-stocking	7	HL (CN & GN when full)
16	Warawewa	5	22.3	Spill-fishing	4	HL only
17	Sangopale	7	33	Pre-stocking	4	Elephants blocking route!

[1] Abbreviations: CF = collective fishing, HL = hook and line, CN = cast net, GN = gill net

6.2.10 Catch composition

Results of the household survey supported marketing study findings (Murray 2004a) regarding the importance of tilapia in rural diets and the dependence of the poorest groups on smaller, low cost tilapias (Figure 6.18 and Figure 6.19). Results are presented only for the three upper-watershed (intervention) villages to illustrate the contribution from the stocked tanks to overall consumption.

Tilapias from all sources combined constituted 81% of total annual *per capita* inland fish consumption (75.9%, 85.8% and 80.9% for poor medium and better-off groups respectively) or 11.6 kg *caput*$^{-1}$ in absolute terms. The proportion of small tilapias (<150g) increased from only 33.8% of the total inland fish consumed by 'better-off' households to 57.8% and 53.8% of 'poor' and 'medium' intake respectively. Only 3.5% of larger tilapias (>150g) came from stocked or 'other' village tank sources whilst the same resource provided 37.3% of all 'small' tilapia. Of the total village tank contribution, 17.3% and 20.3% came from 'other' and 'stocked' village tanks respectively. These findings demonstrate how production of smaller tilapias in the stocked tanks brought substantial benefit directly to poorer households.



	Major irrigation system			Other village tank			Stocked village tank		
	Better-off	Medium	Poor	Better-off	Medium	Poor	Better-off	Medium	Poor
Large tilapia >150g	6.36	4.87	2.13	0.13		0.28			0.07
Small tilapia <150g	3.58	5.62	3.87	0.33	1.27	1.99	0.75	1.33	2.10
Snakehead	0.41	0.57	0.09	0.58	0.26	0.69	0.58	0.63	0.89
SIS	0.27	0.35	0.12		0.08	0.05	0.66	0.05	0.50
Snakeskin gouramy						0.01	0.07	0.03	0.83
Eels (Anguilla Spp.)		0.08	0.11						
Common carp	0.07	0.08	0.02					0.04	

Month

Figure 6.18 Mean annual *per capita* consumption of inland fish varieties by production source in three low-caste villages participating in stocking trials, Dec 00 - Nov 01

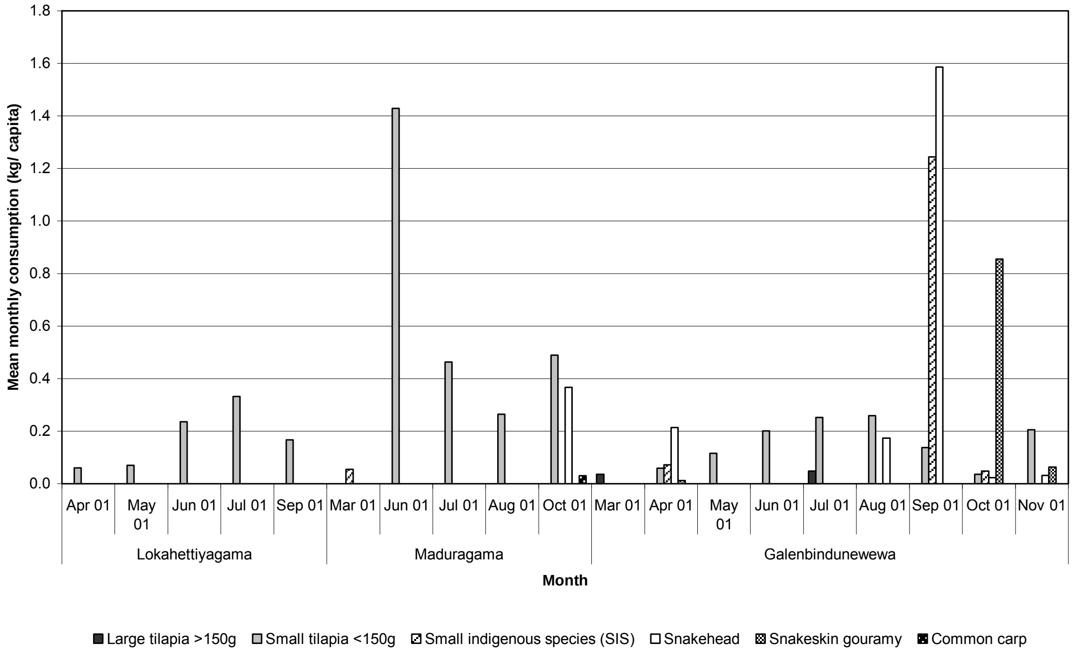


Figure 6.19 Mean monthly *per capita* consumption of inland fish varieties harvested from stocked tanks in three low-caste villages, Nov 00 - Nov 01

Snakehead which constituted 11% of total annual consumption (1.6 kg *caput*$^{-1}$ yr^{-1}) was the second most important inland variety. Some 77% of total consumption originated from village tanks. This brought benefits to all wealth groups but especially to the poor who consumed 43.4% of the total. Most production occurred during the dry season (Sept - Oct) along with lesser amounts caught during minor spill events in April (Figure 6.19). By contrast, 91% of commercially available snakehead was consumed by better-off and medium wealth groups due to its high cost. For the same reasons 79% of common carp was also consumed by the better-off/ medium wealth group. This was only available from commercial sources (with one exception - see below) and in small quantities (mean consumption 0.07 kg *caput*$^{-1}$ yr^{-1}).

Other small indigenous species (SIS) –contributed only 4.9% of total annual consumption (0.7 kg *caput*$^{-1}$ yr^{-1}). Nearly two thirds of the fish consumed (63.5%) came from village tanks, mostly during the collective harvesting period (Sep-Oct). These were consumed in similar quantities by all wealth groups regardless of source. The greatest number of varieties were caught during spill (April) and collective (Sept-Oct) fishing, due to the relatively unselective techniques used on these occasions.

Of the remaining inland varieties, only snakeskin gouramy (*Trichogaster pectoralis*) made a significant additional contribution: 0.3 kg *caput*$^{-1}$ yr^{-1} and 2.2% of total inland fish consumption. First introduced from Indonesia in 1939 (FAO 2004) and again from Malaysia in 1951 (NAQDA 2002) it is now common and had become successfully established in a number of lower to mid-watershed tanks in the watershed survey. The fact that it is established in perennial water bodies but rare in seasonal water bodies fits with the known natural habitats of this fish in its home range and how it is commercially cultured in Thailand (Little, pers. comm.)

Wild seed from Pahala Giribawa (PGB) was used to stock SER and GBW (Chapter 5). Although only a small proportion of the total seed stocked, gouramy proved highly successful in colonizing both these water bodies where according to villagers, none had previously occurred. The species reportedly spoils rapidly, which along with its small size (mostly <100g), effectively exclude it from commercial networks despite good eating qualities. Although it is relatively resistant to the staggered, and to a lesser extent collective harvesting techniques described above, it proved extremely susceptible to ‘mud-fishing’ (Fernando and Ellepola 1969) in shallow residual water storage, where they are readily caught by hand. This provided a 5-6 week window of opportunity post-collective fishing for those without access to more costly fishing gears. In GBW the opportunity was exploited by some of the poorest households including the male children of a female-headed household (Plate 6.2 A and B). Although this household received little benefit from collective fishing due to lack of older male representation, they were still able to procure a daily supply of gouramy for several weeks thereafter.

A **B**

Plate 6.2 A and B: 'Strings' of snakeskin gouramy caught using 'mud-fishing' techniques in the residual storage of GBW tank. Male relatives; a young son (A) and brother (B), provided a regular supply of this fish to a poor female headed household during the 'post-collective harvest fishing period; September 2001.

Of the five tanks stocked in phase 2 trials, only in GBW was there a combination of prior seasonality and spill characteristics which created potential for resident or migrating fish stocks to supplement stocking-related production. This was evident in the catch composition from this tank. Although tilapia became successfully established in GBW some ten years earlier, villagers continued to harvest greater quantities of snakehead during most collective fishing events. This pattern persisted after the stocking intervention with snakehead constituting 35.7% of all reported consumption. With the addition of other SIS, resident species constituted at least 60% of consumption although stocked tilapia and gouramy may have served to augment snakehead production as prey species. However, because results were less clearly attributable to stocking, villagers were generally less satisfied with the outcome than their counterparts in Maduragama, where interventions in both village tanks commenced from a baseline of zero production.

The higher unit area productivity achieved in MAD (section 6.2.6) was also probably due in part to the concurrent stocking of tilapia with snakehead fry. Increased net yields are likely to have arisen through predation on the progeny of the stocked fish thereby reducing propensity for stunting. This also resulted in an important by-catch of snakehead during the collective harvesting period; equivalent to a mean consumption of 0.37 kg *caput*$^{-1}$ yr^{-1} or 12% of total production. By contrast, adult snakehead already resident in GBW probably constrained tilapia production through predation on the stocked fry as well as their progeny.

Interestingly several common carp between 0.7 - 0.9kg were also harvested from MAD. These individuals must have been introduced with fry sourced from Rajangane Reservoir supporting the contention that low-level self-recruitment of the species is occurring in large perennial reservoirs (Murray 2004a).

6.2.11 Seasonal water use

Respondents were asked to identify all water sources exploited by any member of the household for specified purposes during the week prior to each interview. They were then asked estimate the total number of days each resource was utilised for a particular use over the same period. The purpose was to compare the seasonal intensity of different water uses between different water-bodies. This information would provide further insight into (1) the relative importance of competing water uses and (2) multiple-use conflicts associated with stocking interventions.

Relative to the number of households in each village, the largest numbers of different water-resources were exploited by the three smaller upper-watershed communities (Figure 6.20). To illustrate this further, the mean ratio of the number of different tanks exploited by each household was calculated for each village as follows: 0.12, 0.26, 0.37 and 0.28 water-bodies per household in GUR, LHG, MAD and GBW respectively. This indicates that relatively resource rich lower-watershed communities like GUR are more reliant on there own perennial tank(s) whereas upper-watershed communities have greater reliance on external resources particularly during the dry season. They are more likely to restrict access to their own tanks for their own exclusive use for all or most purposes.

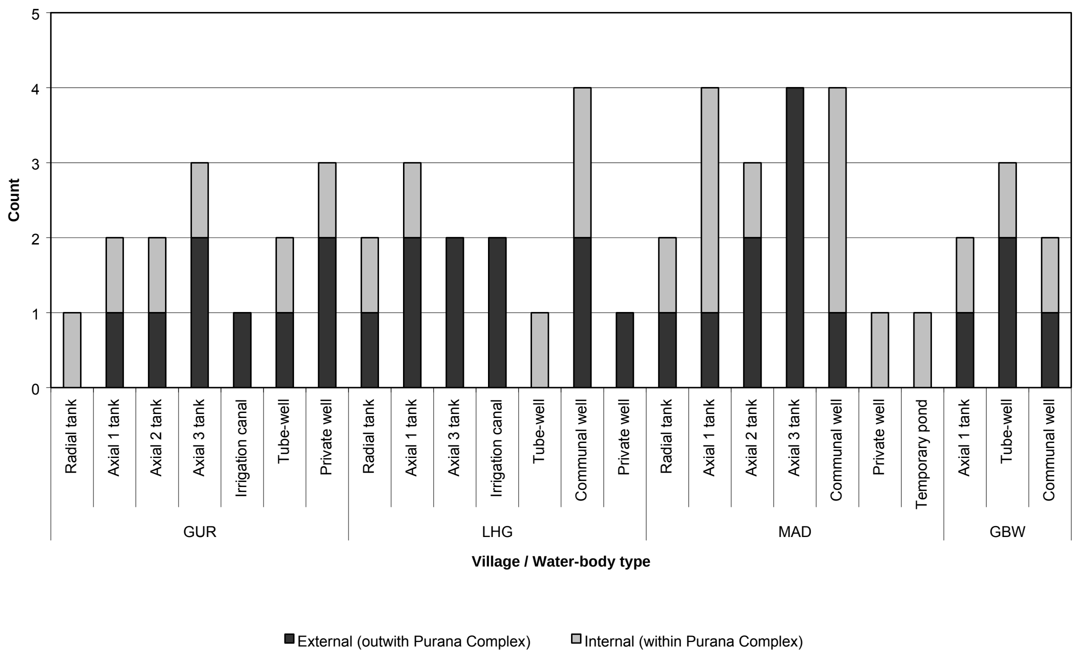


Figure 6.20 Number of different water-bodies accessed by villagers in four low-caste villages, Nov 00 – Nov 01

MAD, the lowest caste community, exploited the largest number of external tanks; 8 of a total of 13 tanks within the watershed over the course of the year. Fishing, live-stock watering and bathing / clothes washing took place in 5, 4 and 3 external tanks respectively. GBW utilized the fewest different water-bodies in absolute terms and used its base tank most intensely (Figure 6.21). Again this was a result of its relative remoteness and unusually large size of the GBW base tank relative to the number of households in the village.

Water use was clearly most intense in each of the village’s axial ‘base’ tanks. The same tanks were also regularly put to the widest range of uses. This meant that these tanks had the greatest conflict potential; particularly the lower order / semi-seasonal axial tanks.

Bathing and washing followed by livestock watering were the most frequent uses of all tanks; both internal and external (Figure 6.21). Most respondents adopted a relatively relaxed attitude towards common access by neighbouring villagers for these essential activities and they are usually well-tolerated on a reciprocal basis. Some exceptions were observed in the case of extreme caste polarisations.

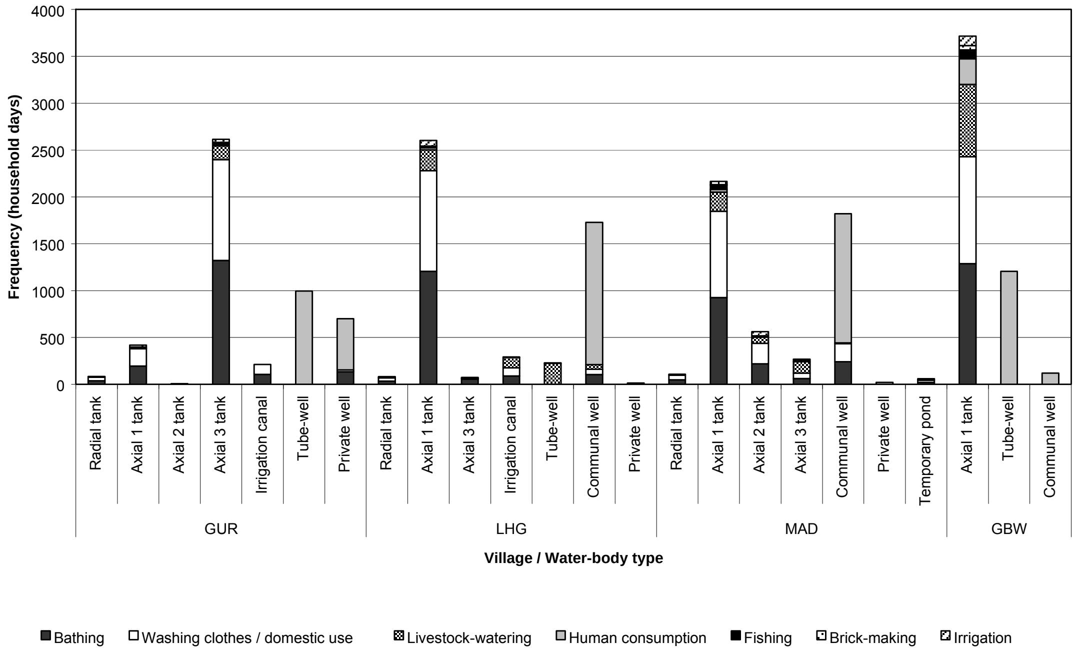


Figure 6.21 Frequency of water use from different resources by 41 'panel' households in four low-caste villages, Nov 00 – Nov 01

Only in GBW was there significant use of tank water for direct human consumption. This was collected from the littoral areas several months post-inundation by some of the poorest households. Although the village had its own tube and community well, groundwater salinity problems meant that most households relied on tube-wells in neighbouring Kahatagaswewa.

All the remaining water uses were far more sporadic in frequency. Negligible irrigation activity occurred under GUR[t] as many villagers prioritised cultivation on lands with assured irrigation supply from nearby Rajangane Reservoir. Instead, there was greater reliance on GUR[t] for secondary activities including bathing, washing and cattle; which could be watered and grazed around the tank throughout the year. All other tanks in thus survey were exploited for intensive cultivation during the *yala* season (Appendix 16).

Removal of sediments for brick-making took place in each village during the minor (Feb-Mar) and major (Aug-Nov) inter-monsoonal dry seasons, with no discernable positive or negative impacts on other water users. Although many households regularly harvested aquatic plants, unfortunately no consistent data was solicited on this activity in this part of the survey.

A total of 237 separate fishing events were recorded by the 41 households in the survey. MAD and GBW the two lowest cast communities were fished most frequently, with activity on 85 and 96 days respectively. This compares with only 34 events in GUR and 20 in LHG; the highest caste village. MAD and GBW were again also more likely to exploit external tanks for their subsistence (Figure 6.22).

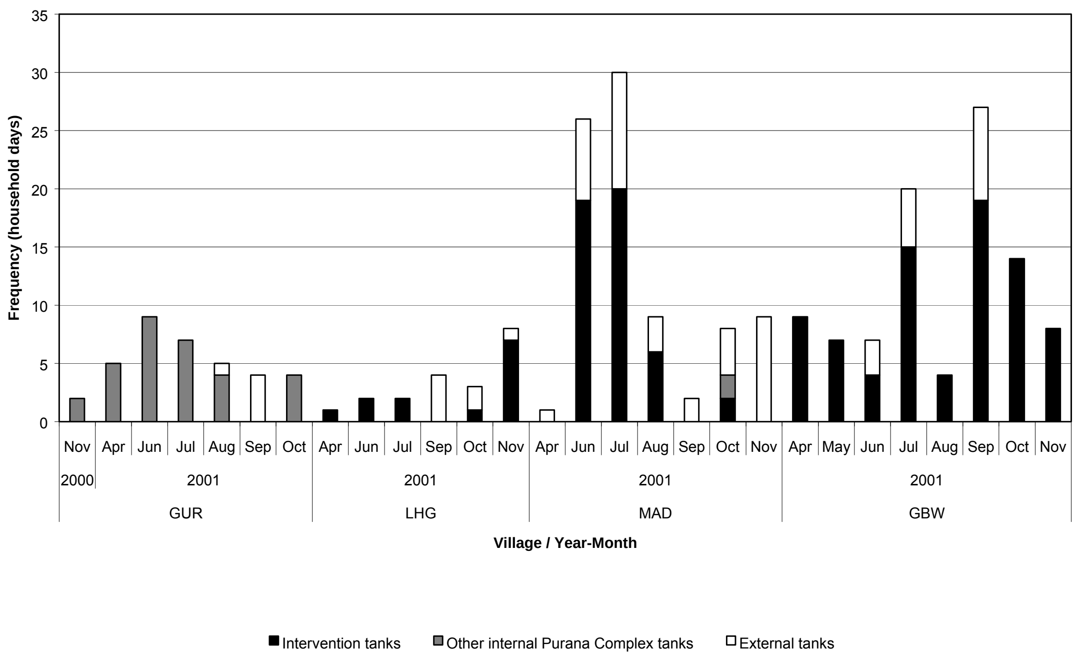


Figure 6.22 Monthly frequency of participation in fishing events in different water bodies by 41 'panel' households in four low-caste villages, Nov 00 – Nov 01

Poor and medium households were responsible for 73% and 15% of total fishing events, while representing 36% and 34% of the survey panel respectively. Nearly all 'better-off' household participation was recorded in MAD and GBW. Only 2 days were recorded in GUR and none at all in LHG. Better-off households constituted 29% of the entire survey panel.

Weighted by village and wealth (i.e. scaling from sample to population size), these results correspond to a total of 854 fishing events undertaken by all households in the three intervention communities. These results only incorporated part of the SER effort (i.e. through informal participation of MAD households). Nor did the survey solicit information on ‘external’ participants fishing in ‘internal’ tanks. The phrasing of the question also meant that each event could incorporate participation by one or more household members in a given water-body on a particular day. These factors mean that the scope of this survey was considerably less inclusive than the direct observational techniques which solicited information regarding all individual participation in all five phase 2 intervention tanks (Chapter 5). However, ultimately only 355 separate fishing events involving 484 participants were recorded. In other words, the observational / key informant methods appeared to capture no more than half of the fishing activity which actually occurred over the course of the year. Nevertheless, both surveys do clearly demonstrate one significant outcome; the far greater reliance of poor households in upper-watershed areas on subsistence fishing for their livelihood.

As one of the most recurrent activities with great potential for negative interaction with fishing, bathing seasonal profiles are also presented in Figure 6.23. Tank bathing was least frequent during April (Quarter 2) when there was intense daily rainfall and highest during periods of intense agricultural activity. Levels also declined substantially in the upper-watershed tanks towards the end of the dry season when suitable water resources were most scarce.

Bathing was concentrated in each of the village ‘base’ tanks; GUR^{t}, LHG^{t}, LUN and GBW^{t} which accounted for 77.7% of total bathing days (data not shown). An additional 10.7% of events took place in other internal and external village tanks, 8.1% in communal and private open wells, and the remaining 3.5% in irrigation canals near GUR and LHG and a flooded quarry in MAD. Reliance on these secondary resources was greatest during the dry season as the quality of residual water storage in the base tanks deteriorated. In LHG, GBW collective fishing activity clearly contributed to the deterioration and to a lesser extent also in MAD (Chapter 5).

In LHG[t] protracted buffalo-wallowing following collective fishing during September compelled most villagers to bathe in an axial 1 tank belonging to the neighbouring village of Potanagama. This resulted in another minor conflict when a group of LHG women began to use a site informally reserved for local Buddhist monks. Similarly, protracted fishing in GBW resulted in most villagers becoming increasingly reliant on a neighbouring axial 1 tank between September and November (Kahatagaswewa). In both these cases this was despite informal agreement with the neighbouring villages with whom there were relational and / or institutional linkages and only moderate differences in caste status. Potanagama were a village of drummers slightly lower in status than the LHG blacksmith caste.

The lowest caste villagers in MAD were necessarily more self-reliant; utilising a communal well constructed rather unusually within KBW tank bed where it remained submerged for much of the year. Although the location exploited elevated ground water levels it also meant the well required de-silting on an annual basis. The well became the main bathing resource in October when both LUN are KBW were reduced to small turbid pools. A number of villagers also exploited Pahala Diulwewa the largest perennial tank in the survey, located 1.5km from the village. The size of this tank effectively made it an open access resource for anyone who wished to bath there.

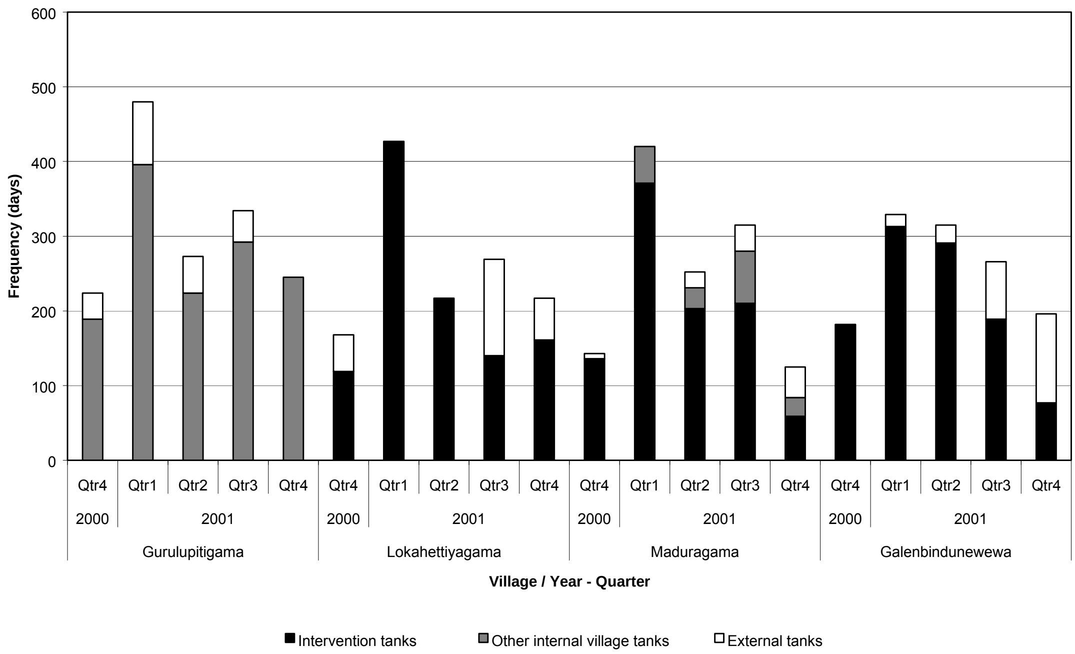


Figure 6.23 Seasonal frequency of bathing days in internal and external village tanks by households in four low-caste villages, Nov 00 – Nov 01

6.2.12 Multiple water-use conflicts

Respondents were asked to describe any conflicts that their household had experienced relating to the use of any water resource utilised by any household member since the previous visit. These included; village tanks inclusive of intervention tanks, a range of open well types, tube-wells and local canals. Conflicts resulted from negative externalities related to different water uses and competition for single specific uses (Chapter 2). Unsurprisingly there was a degree of reluctance to discuss conflict situations relating to specific local individuals or neighbours. This restraint diminished somewhat as the survey progressed and rapport and trust improved.

All the conflicts recorded in these trials were 'low level', i.e. they were resolved with no requirement for external mediation, were relatively transient and resulted in none of the physical confrontation observed in the phase 1 trials. The overall frequency was also low, with only 58 water-use related conflicts recorded during 996 interviews. Results were cross-tabulated against four background variables; type of tank or water resource; village, wealth rank, and respondent gender. The significance of any differences in the total number of conflicts related to tank water use was also assessed against each of the latter three background variables using Pearson's χ^2 test. Finally broad seasonal trends in tank water use were assessed by cross-tabulation.

Some 86% of conflicts were recorded in 14 tanks inclusive of all the intervention tanks. Conflict frequency was lowest in radial (1 / tank), and highest in axial 1 tanks (6.4 / tank), decreasing again in higher order axial tanks (4.3 / axial 2 tank - Figure 6.24). This frequency inversion probably occurred because axial 1 tanks were subject to the most intensive multiple-use in relation to their size, i.e. they were the 'base' tanks of all the upper-watershed villages. Conversely, radial 'base tanks' are rare and also less intensively used. Only one radial tank, Ulpathwewa (one of the phase 1 intervention tanks) in the watershed survey of 120 tanks fell into this category.

Conflicts took place in nearly three quarters (73%) of the internal village tanks; 50% being associated with the five intervention tanks. The balance of 28% was associated with the use of external tanks. Conflicts occurred in one fifth (19%) of all the external tanks whose use was reported in the previous section.

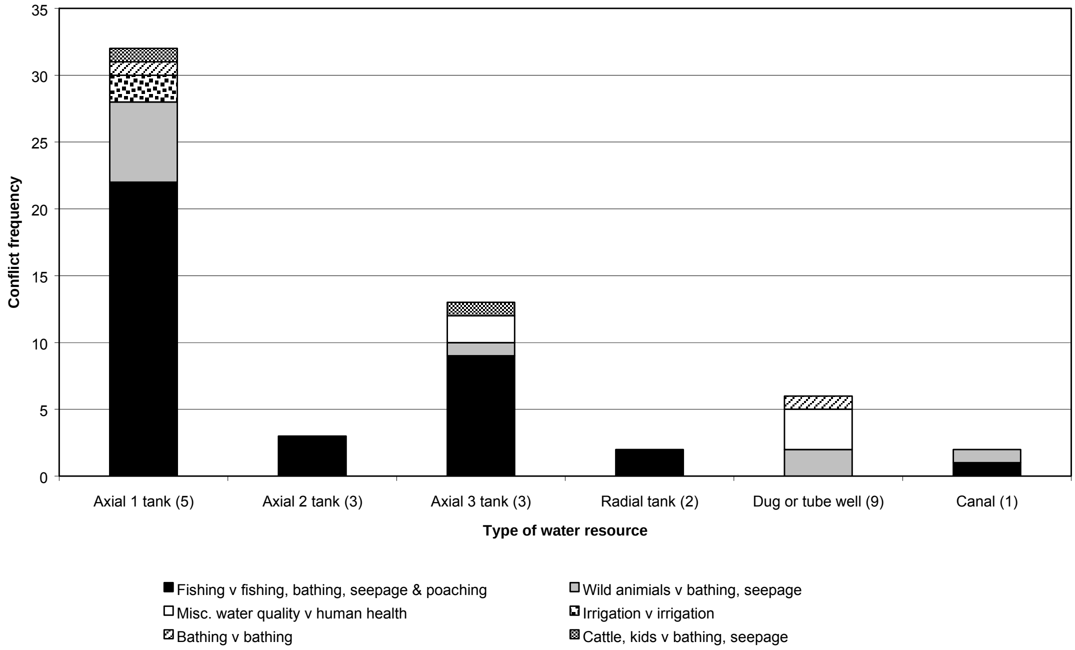


Figure 6.24 Frequency of multiple water-use conflicts associated with different tank classes and other water resources in four low-caste villages, Nov 00 – Nov 01 (numbers of water-bodies indicated in brackets)

Highly significant differences ($P < 0.01$) in the total number of conflicts were observed between the different villages (χ^2 = 11.94 (3) 0.008). Most tank-related conflicts (31%) were recorded in GBW (Figure 6.25). This was surprising given that the consequences of poorly coordinated management appeared much worse in LHG where tank bathing amenities were effectively lost for 4-6 weeks (Chapter 5), yet this village recorded only 12% of the total conflicts. In addition to the more typical water quality problems, much of the discontent in GBW was associated with 'inequitable' distribution of the collective harvest (Chapter 5). In the other intervention tanks collective harvesting was more subordinate to staggered harvesting. This suggests that where existing village institutions are poorly representative of poorer sections of the community greater conflict potential exists for collective harvesting than staggered harvesting.

Levels of the most frequent conflict category: 'fishing v water-quality', were similar in GBW and GUR. This suggests that the stocking interventions were unlikely to have elevated this problem above pre-existing levels. In MAD all conflicts were much lower and mainly associated with poaching in Hangogamawewa, the un-stocked radial tank at the periphery of the village. This reduced level must be set against a pre-existing background of strong social cohesion in this village.

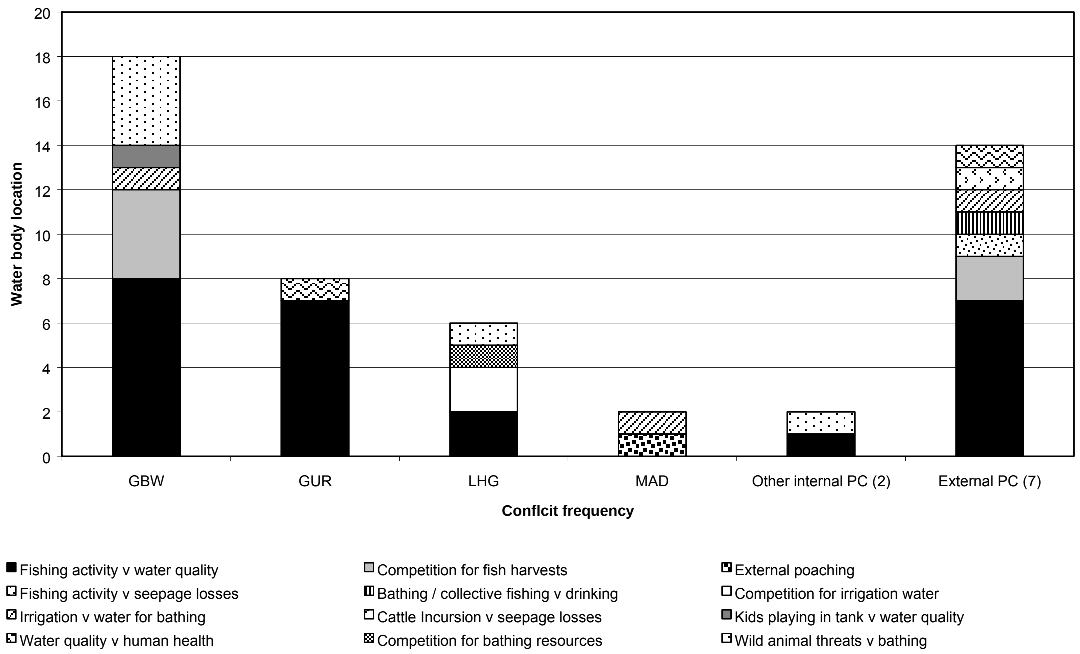


Figure 6.25 Frequency of conflicts related to water use in village tanks, Nov 00 – Nov 01

No consistent variation was found between the number and type of conflicts reported between different wealth ranks (χ^2 = 0.29 (2) 0.86). Overall a mean of 1.4, 1.5 and 1.33 incidents were reported per better-off, medium and poor household respectively. However men were significantly more likely ($P < 0.05$) to air their grievances than women (χ^2 = 5.55 (3) 0.018), though again there was no clear difference between the types of conflicts males and females were likely to report. Although only 4 of the 37 survey households were female headed, women were more likely to be available for interview in their homes. They thereby accounted for 577 of the 996 interviews held over the course of the year but reported only 23 of the total 58 conflicts. Again this appeared to reflect a greater reluctance to discuss personal conflicts rather than ignorance of them.

Figure 6.26 clearly shows the progressive increase in conflicts as water levels decrease, reaching a peak in the driest month; September. The secondary peak in April was largely due to elephant incursions in GBW which restricted bathing activity. The figure also shows once again, how the negative impact of intrusive fishing on bathing activity was the most frequent source of grievance.

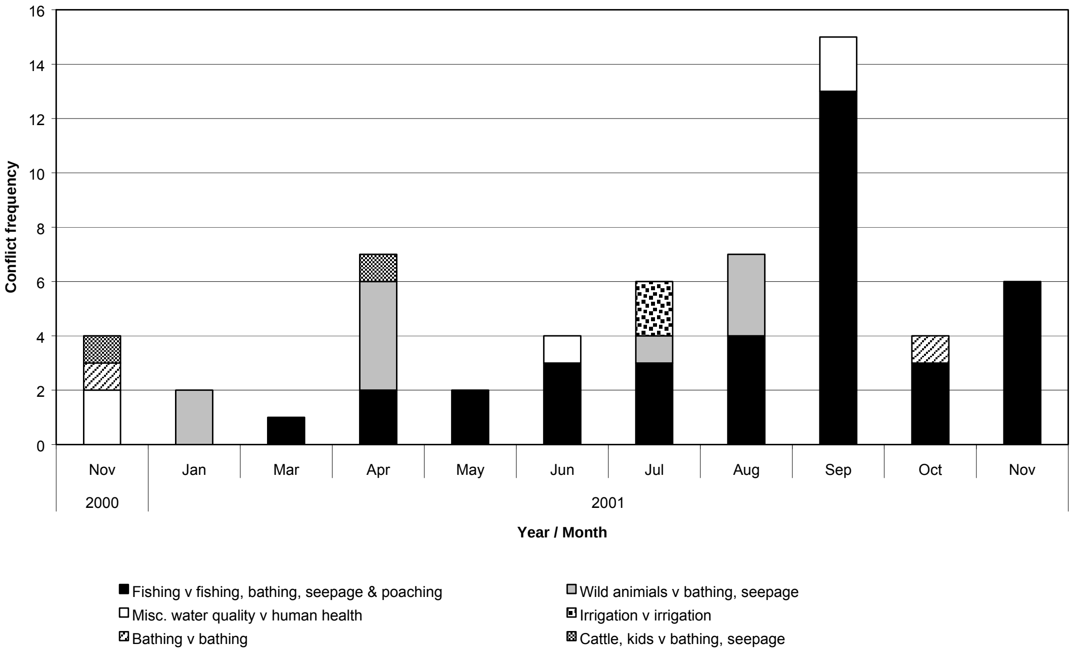


Figure 6.26 Seasonal frequency of tank related water-use conflicts in four low-caste villages, Nov 00 – Nov 01

In summary, these findings indicate that the same quality of observability which makes ‘base’ tanks desirable for stocking by deterring poaching, also increases conflict potential. In other words increased observability will typically be accompanied by more intensive multiple-use. The question then is, do these and the less tangible conflicts associated with village power hierarchies described in Chapter 5 outweigh the benefits of stocking? The question will be returned to in the following section in which results of the PIM survey are presented.

6.3 Participatory impact monitoring (PIM) survey results

Although results in the previous section were the outcome of a social survey, as in Chapter 5 data was collected close to the actual time when events took place and though based on farmer recall, much of it was highly quantitative. In this (PIM) survey I was concerned to understand farmer perceptions on the outcomes of stocking initiatives and how these might relate to the observed or 'measured' outcomes. Beyond the obvious step of data triangulation, there were also methodological implications in the application of multiple techniques. The 'real time' or longitudinal surveys involved considerably more time and effort in data collection and analysis. These characteristics are among the reasons why the use of these traditional, formal and structured techniques have been largely excluded from the participatory tool kit. There would therefore be a comparative aspect to this section, i.e. how far could the main conclusions of the previous surveys have been more practically assessed, with less effort or intrusion, by the application of a 'quick and dirty' *a posteri* PIM technique?

A wealth stratified PIM survey was carried out in the three phase 2 intervention villages immediately upon completion of the trials. The survey consisted of four components; the first based on recall of fishing activity, two ranking exercises relating to intervention outcomes and a final section in which respondents were asked whether they would consider repeating the stocking exercise. The methodology, including the sampling design, is presented in Chapter 3 and results in the following sections.

6.3.1 Seasonal fishing activity

The purpose of the first part of the survey was to assess recall of any fishing activity in stocked or un-stocked water bodies that had occurred during the intervention time-frame. For each specified location respondents were asked to recall the number of household members participating, the number of days fishing that took place and approximate yields during each seasonal fishing period; pre-spill, spill, post-spill staggered, low-water collective, post-collective staggered (Chapter 5). Results were weighted by relating sample population to the total number of households per wealth rank / village to give an indication of the total fishing activity taking place with each community over the year. Household occupancy levels were also taken into consideration.

In this way a total of 483 individual fishing events were estimated of which 395 took place in stocked tanks; 13, 274 and 197 in LHG, MAD and GBW respectively (Figure 6.27. These frequencies were comparable with the outcome of the observational survey but once again less than half the level assessed in the longitudinal household questionnaire. In other words, only by regular observations over time could reasonably accurate data of this kind be collected. Other trends were consistent with both surveys; participation was dominated by poor and medium wealth households (60% and 31% respectively), the highest participation rates were recorded during the 'post-spill staggered harvesting' periods while participation by better-off people was restricted almost entirely too collective fishing events.

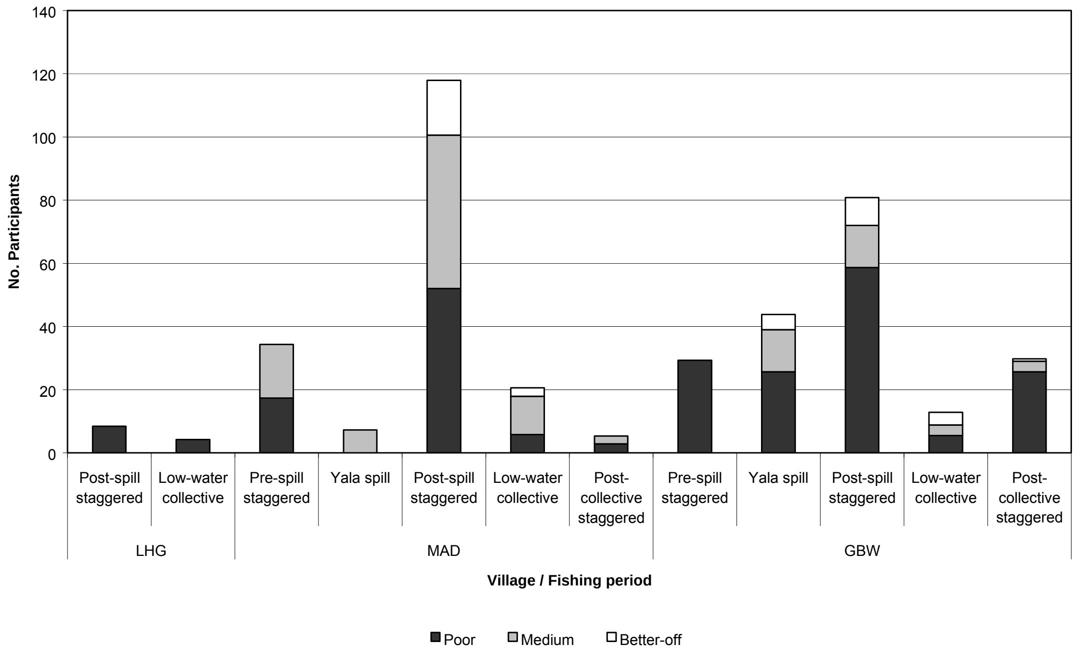


Figure 6.27 Estimated frequency of seasonal fishing activity in stocked village tanks in three low-caste upper-watershed villages, Nov 00 – Nov 01 (sample results weighted according to population characteristics)

Relatively little of the external fishing activity recorded in the household survey was detected in this survey. This was almost entirely restricted to MAD where 21 days were reported in Hangogamawewa and 67 in other external tanks. Nearly 68% of this activity took place during the pre-spill and spill periods (data not shown). A decline in external activity thereafter, is consistent with people in MAD starting to fish from the two stocked tanks in the village. Villagers in both LHG and to a lesser extent GBW were much less willing to discuss their own participation in staggered harvesting, especially better-off and medium wealth households.

Fishing yield recall results were also averaged and weighted according to the population numbers within each village / wealth rank sub-group to give a further estimate of total production (Table 6.2). These results are compared with those of the other surveys in section 6.4.

Table 6.2 Total yield by wealth rank and area yields from stocked tanks in phase 2 trials, Nov 00 – Nov 01; based on participant recall

Wealth rank	Tank yield (kg)				
	GBW	LHG	LUN	KBW	Grand Total
Better-off	24	0	117	0	141
Medium	21	46	111	164	343
Poor	37	38	97	89	261
Grand Total	82	84	325	253	744
Area yield (kg ha^{-1} at 50% MWS)	19.5	12.4	171	281.1	53.9

6.3.2 Optimal outcome ranking

The purpose of this exercise was to investigate which impacts participants would ideally liked to have come about, regardless of actual *a posteri* outcomes. This would contribute to the assessment of how likely it was that the interventions would be repeated. Summary statistics of responses pooled for all villages are shown in Table 6.3. Friedman's test revealed a highly significant difference between ranked criteria (χ^2: 187.5 (5) < 0.01). To detect the loci of these differences, all two-way criteria permutations were subjected to the Wilcoxon's signed ranks test.

Results indicated highly significant differences (P <0.01) between all but the first two combinations (Table 6.4). In other words there was reasonable consensus between all respondents regardless of other background variables; village, wealth, gender or age that improved social cohesion and water management were jointly the most important outcomes, followed jointly by food security and income generation / substitution. Improved knowledge and awareness was next most important and recreational activity least important. These results suggest that any stocking interventions which have negative impact on social cohesion or water conservation are likely to be unsustainable. They also point to a reason for the failure of many traditional stocking programs in which technical production outcomes have been over-prioritised and social transactions neglected.

Table 6.3 Descriptive statistics for the optimal outcome ranking exercise

Ref	Category criteria	N	Mean rank*	Std. Deviation
1	Social cohesion / equity	57	1.70	0.97
2	Water management	57	1.85	0.73
3	Food security	57	3.47	1.22
4	Income generation / substitution	57	3.82	1.11
6	Knowledge and awareness	57	4.69	1.04
5	Recreational activity	57	5.47	0.86

*Criteria ranked from 1 – 6, where; 1 = most significant, 6 = least significant

Table 6.4 Results of Wilcoxon's signed ranks test for the optimal ranking exercise

Category criteria combinations	Z	Asymp. Sig. (2-tailed)
Water management - Social cohesion / equity	-1.024	.306
Income generation / substitution - Food security	-1.077	.282
Recreational activity – Knowledge and awareness	-3.465	.001
Knowledge and awareness – Food security	-4.206	.000
Recreational activity – Food security	-5.919	.000
Social cohesion / equity - Food security	-5.339	.000
Water management - Food security	-5.165	.000
Knowledge and awareness - Income generation / substitution	-3.520	.000
Recreational activity - Income generation / substitution	-5.226	.000
Social cohesion / equity - Income generation / substitution	-5.626	.000
Water management - Income generation / substitution	-6.203	.000
Social cohesion / equity - Knowledge and awareness	-6.513	.000
Water management - Knowledge and awareness	-6.433	.000
Social cohesion / equity - Recreational activity	-6.508	.000
Water management - Recreational activity	-6.623	.000

6.3.3 Ranking and scoring of indicators of change

The analysis of these survey results was complicated by the large number of indicators; both positive and negative and the multiple-response methodology employed (Chapter 3). To address the first problem, results were subjected to the following data reduction step. Frequencies of all positive and negative impacts were calculated regardless of ranked position. The mean number of citations per participant in each village (and wealth group where relevant) was then calculated to account for differences in sample size. Indicators that were not cited at least 0.4 times per participant (i.e. by 40% of respondents) in at least one village were descriptively assessed and excluded from further statistical analyses. Indictors cited more or less than this threshold are henceforth prefixed as ‘principle’ and ‘minor’ respectively.

Figure 6.28 and Figure 6.29 show village-wise frequency plots for the entire dataset broken down by minor / principle impact groups and individual participant-indicators respectively. The 57 respondents in the 3 villages made a total of 207 citations with nearly three times as many positive (148) as negative ones (59). There was a modal number of 4 citations per participant (by 16 respondents) and a maximum of 8 citations in one instance only. Only three respondents perceived no change whatsoever; two medium wealth households in LHG and one better-off household in MAD.

While respondents were probably less willing to highlight negative outcomes, the magnitude of this difference suggests that most villagers perceived some net gain; direct or indirect. However, Figure 6.28 shows clear differences in overall impact between the three villages. Some 50.8%, 33% and 9.4% of responses were negative in LHG, GBW and MAD respectively, while the mean number of citations per respondent ranged from 2.8, 4.5 and 3.9 in the same villages. These findings underscore those of the two previous surveys; relatively, MAD trials were most successful, GBW held an intermediate position while the worst outcome was in LHG where negative citations marginally outweighed the positive. The low citation frequency in LHG also indicated that some participants remained poorly aware of any impacts.

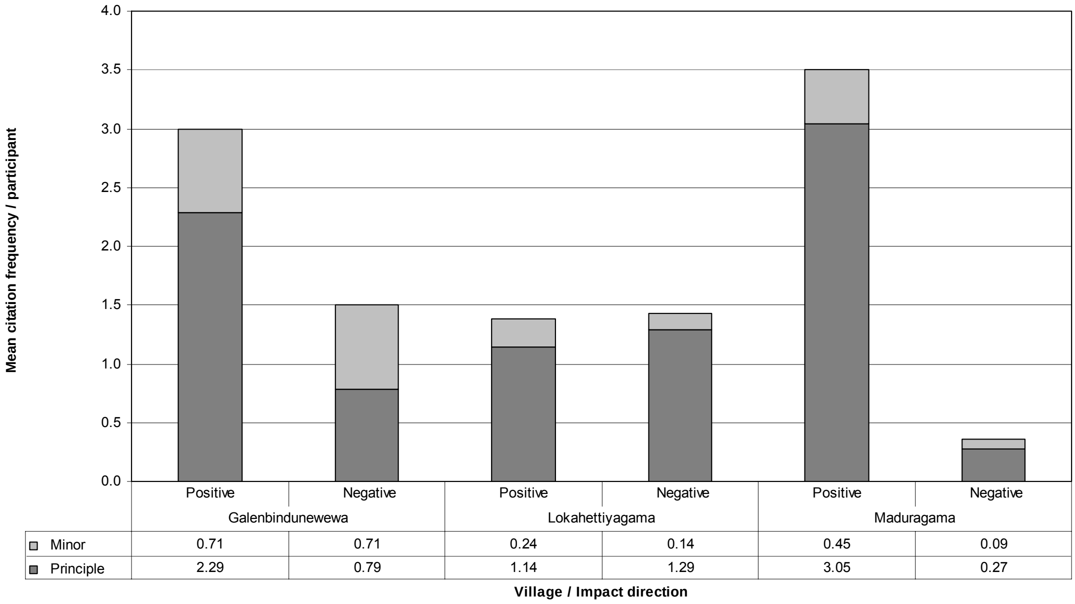


Figure 6.28 Citation frequency of aggregate positive (+) and negative (-) impacts by principle / minor indicator group and village location

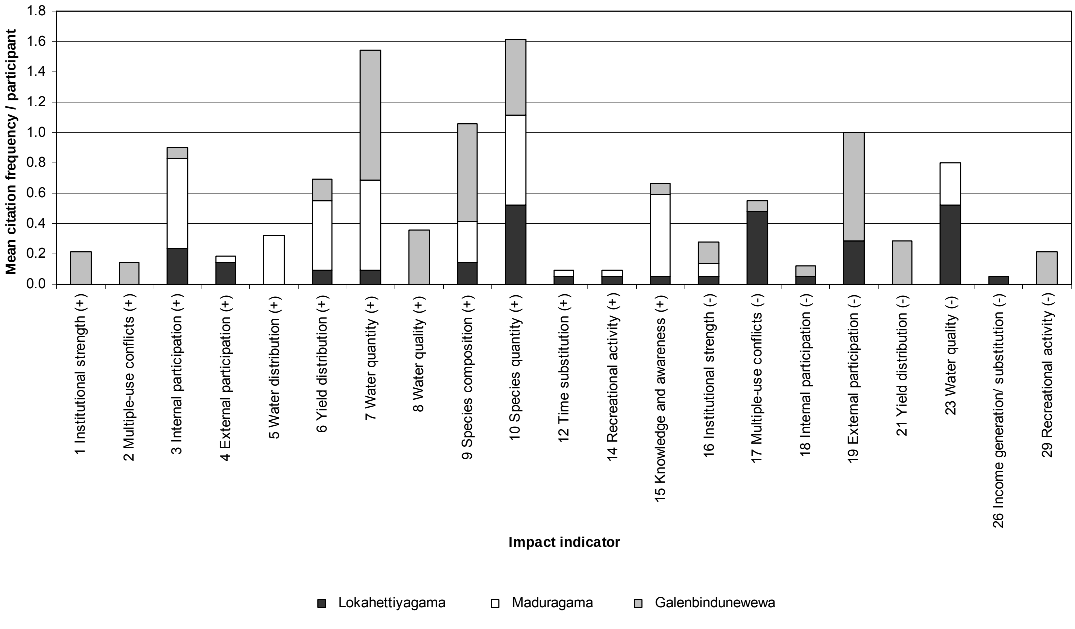


Figure 6.29 Frequency of positive (+) and negative (-) impacts by 'participant-indicator' and village location

The doubling of the number of basic indicators from 15 to 30 in the directional design (i.e. allowing for negative and positive outcomes) yielded zero frequencies in eight instances. These consisted of seven negative indicators; water distribution, water quantity, species variety, species quantity, income substitution, time substitution and knowledge / awareness and one positive indicator; 'sale of fish'.

There were a total of 40 'minor' citations by 30 respondents relating to 12 of the 30 participant indicator types; 7 positive and 5 negative (Figure 6.29). The greatest frequencies of minor categories were recorded in LHG and GBW, while there were fewer indicators and greater consensus in MAD. The citation frequencies of the various minor indicators are discussed next, followed by an assessment of the citation and ranking outcomes for the principle indicators.

As noted earlier, prior to intervention many farmers with irrigated lands expressed concern regarding the threat of increased percolation losses they perceived would result from invasive fish-netting methods. The absence of negative responses on this indicator suggests that the adoption of hook and line methods during cultivation periods helped successfully mitigate such conflicts. However the finding also corresponds with an earlier observation; that such sentiment can also be interpreted as a desire to maintain position in the village hierarchy.

No respondents reported any household involvement in the retail of fish caught from seasonal tanks. However a small number of young men were reported and occasionally observed doing just this in both GBW and LHG. The activity was also captured in both earlier surveys. Sales were restricted to the same village, with tilapia retailing for approximately Rs 20-25/kg, i.e. approximately half the cost of commercial produce. Once again, taboos attached to subsistence fishing and juvenile participation probably led to under-reporting. Direct interview methods such as the one employed here therefore appear poorly suited to collecting this kind of information.

Only one of the five commercial two-wheeler fish vendors in the intervention villages (three in LHG and two in MAD) reported a marginal negative impact from local production on his sales within the village. This was a medium wealth ranked vendor from LHG. None of the vendors participated in the seasonal tank fishery though all were broadly supportive of the wider social benefits which they perceived had gone to other villagers. All required assured supplies of larger, 'off-flavour' free fish from perennial fisheries for their business, and all retained any surplus left over from their daily sales-rounds for their own household consumption.

Prior to the GBW intervention, there were well established informal reciprocal access arrangements with Ralapanawe, a neighbouring village of blacksmiths (an intermediate status caste - Chapter 5). Consequently, several respondents, all of low to medium wealth, cited a decrease in recreational activity following regulation of the GBW fishery. However this was ranked as the least significant impact by each of the three respondents citing it. Several nearby abandoned ‘jungle’ tanks provided opportunities for continued recreational fishing activity.

Perhaps most significant amongst the minor indicators was the small number of citations relating to positive or negative institutional strengthening which must be viewed as a significant common constraint to sustainable adoption. While a small number of respondents in each village cited institutional weakening, only three respondents in GBW felt their village institutions had been strengthened. This was due to the success of the fishing society regulating access prior to and after collective fishing. However, lack of positive responses in MAD was mitigated by a common perception that the village already had very strong and active institutions. This contention was supported by neighbouring villagers in LHG some of whom despite their higher-caste status, candidly admitted they wished they could emulate their success.

‘Principle’ indicators included 6 positive criteria: internal participation (citation frequency (CF) = 19), fish yield distribution (CF = 14), water quantity (CF = 27), species composition / variety (CF = 18), species quantity (CF = 31) and knowledge and awareness (CF = 14) and three negative criteria: multiple-use conflicts (CF = 11), increased external participation (CF = 16) and decreased water quality (CF = 17). Mean participant citation frequencies corresponding with these figures are presented by village location and wealth rank in Figure 6.30.

Loss of water quality was the only negative principle impact cited in MAD; by 6 respondents. The problem was most pronounced in GBW where 11 respondents attributed this at least in part to increased fishing activity. Conversely, in GBW five participants including four women cited an improvement in water quality compared to previous years. They felt this was due to the increased regulation of post collective-fishing using nets. Two of the same respondents cited reduced multiple-use conflicts for the same reason (Figure 6.29) while an equal number felt they had increased. In LHG a much larger total of 10 respondents, almost half of those questioned, felt that non-specific multiple-use conflicts had increased.

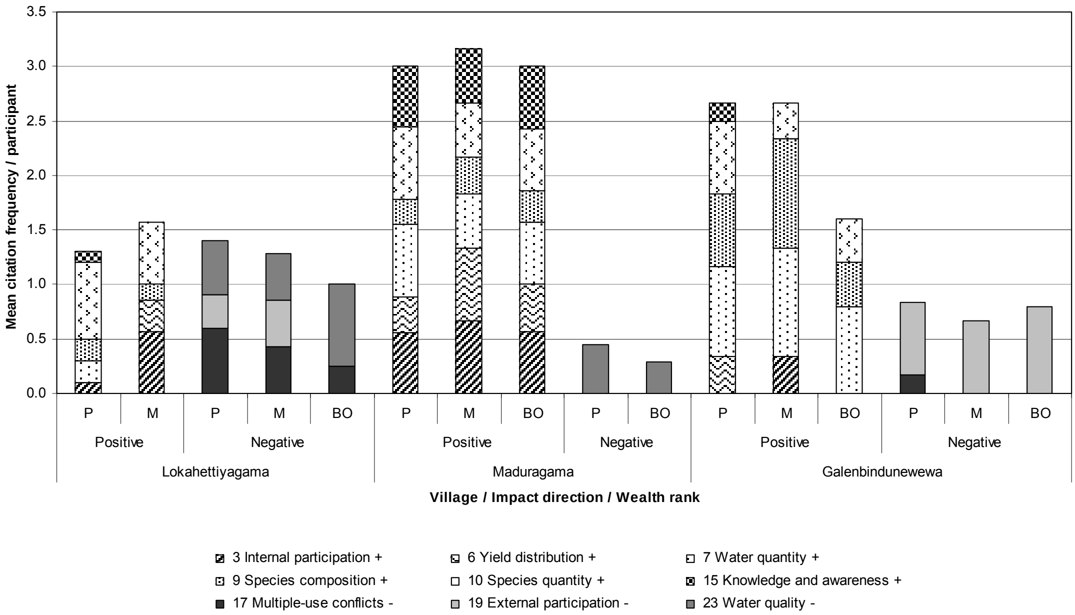


Figure 6.30 Mean citation frequency of positive (+) and negative (-) impacts for 'principle participant-indicators' (n > 10) by PIM respondents by wealth and village location

Increased external participation was viewed negatively as 'informal poaching' by a broad spectrum of respondents in LHG and especially GBW. Increased internal participation was viewed positively by all wealth groups in MAD but only by small numbers of poor and medium respondents in LHG and GBW. Only two better-off respondents, one in GBW and one in MAD, viewed all fishing negatively, both internal and external, associating it with unsanctionable 'poaching' and a threat to water quality.

Improved fish yield distribution also found broad and substantial consensus (CF = 10) in MAD. In GBW only a few poorer households, that were responsible for informally initiating collective fishing, responded positively whereas four better-off and medium wealth participants felt distribution had become less equitable as a consequence of unorganised 'collective' fishing (Chapter 5). Members of one female headed household and two households whose men were involved in off-farm labour were particularly aggrieved at being excluded due lack of male representation on the main days of fishing.

Significant numbers of respondents in both MAD and GBW felt that irrigation management was carried out more judiciously to conserve water for fish production. However, only in GBW did villagers feel that this improved management extended to more equitable distribution of water (CF = 5 or 36% of respondents).

Only in MAD did a substantial number of villagers feel that they had benefited from improved knowledge and awareness. Significantly, many had previously believed that it was not possible to usefully increase fish production in such small water-bodies as MAD and KRB.

There was a general perception in all villages and wealth categories, particularly among the ‘poor’, that fish production had increased to some degree. Similarly many respondents also appreciated a qualitative improvement in fish composition. This was mainly attributed to the stocking of tilapias obtained from the Rajangane fishery. These were viewed as being superior to the normal resident tilapia populations found in small village tanks in both appearance and eating quality, though these perceptions were not substantiated by any other data. In MAD villagers also captured a substantial number of snakehead where previously there had been none.

In the final part of this analysis ranking outcomes were assessed. Split ranks were assigned to all indicators which remained un-cited by participants and the results subjected to Friedman’s test. The result was highly significant ($\chi2$ = (359.6 (26) $p < 0.01$) indicating areas of broad consensus for all respondents regardless of location. Next all pair-wise combinations of the principle indicators were subjected to Wilcoxon’s test to identify the main sources of these differences (Table 6.5).

The results indicate that increased yield and improved water management were jointly ranked significantly higher ($P < 0.05$) than all other impact criteria; positive or negative by all respondents. Reduced water quality was also ranked significantly higher than multiple-use conflicts. No other pair-wise comparisons reached significance; though increased internal participation, increased species composition, and loss of water quality were ranked higher on average than improved yield distribution, improved knowledge, multiple-use conflicts and external participation.

Table 6.5 Asymp. Sig. (2-tailed) results of Wilcoxon's pair-wise comparisons on 'principle' impact indicators with data pooled for all intervention villages. Numeric entries indicate row criterion has higher mean rank than corresponding column criterion. Significant differences (P < 0.05) are shown in bold.

Indicator code & name	Impact Indicator code (see row entries)								
	3	**6**	**7**	**9**	**10**	**15**	**17**	**19**	**23**
3 Internal participation +		0.11		0.67		0.32	0.64	0.53	
6 Yield distribution +									
7 Water quantity +	**0.012**	**0.001**		**0.006**	0.83	**0.001**	**0.001**	**0.001**	**0.029**
9 Species composition +		0.25				0.76	0.63	0.76	
10 Species quantity +	**0.012**	**0.001**		**0.001**		**0.002**	**0.001**	**0.006**	**0.026**
15 Knowledge +		0.82						0.85	
17 Multiple-use conflict -		0.79				=			
19 External participation -		0.54							
23 Water quality -	0.59	0.22		0.47		0.18	**0.047**		

The analysis was run a second time on individual village data-sets (Table 6.6). This confirmed many of the differences between the villages revealed by the simple analysis of citation frequencies. In LHG deterioration in water quality was significantly more important than all other criteria (P < 0.05). In tandem with this, one other negative indicator; 'multiple-use conflicts' ranked significantly higher than four other indicators. A third, positive indicator; 'species quantity' (i.e. total yield) ranked midway between the two negative indicators. However, many respondents associated this benefit with a notional common good rather than significant individual gain.

In MAD, two of the three negative principle indicators; 'multiple-use conflicts' and 'external participation' were significantly less important than all other indicators, while increased species composition was significantly less important than the four highest ranked indicators' all positive; 'internal participation', 'water quantity', 'species quantity', and 'knowledge and awareness'.

In GBW two positive indicators; 'internal participation', 'knowledge' and two negative indicators; 'multiple-use conflicts' and 'water quality' were jointly significantly more important than four other indicators. Improved yield distribution was significantly more important than three other criteria; however the earlier citation frequency analysis already indicated that equal numbers of respondents perceived deterioration on the same criteria.

Table 6.6 Results of Wilcoxon's pair-wise comparisons on 'principle' impact indicators by intervention village. Entries indicate median ranks of row criteria which are significantly greater than referenced indicators (P < 0.05: Asymp. Sig. (2-tailed))

Indicator code & name	Intervention village		
	LHG	**MAD**	**GBW**
3 Internal participation +		9, 17, 19	7, 9, 10 ,19
6 Yield distribution +		17, 19	7, 9, 19
7 Water quantity +		9, 17, 19	
9 Species composition +		17, 19	7
10 Species quantity +	6, 7, 9, 15, 19	9, 17, 19	7
15 Knowledge +		9, 17, 19	7, 9, 10, 19
17 Multiple-use conflict -	6, 7, 15, 19		7, 9, 10, 19
19 External participation -			
23 Water quality -	3, 6, 7, 9, 15, 19	17, 19	7, 9, 10, 19

Finally the analysis was run on data pooled for all male and female respondents. The results (data not shown) indicated that both males females ranked improved water quantity and fish yield significantly higher ($P < 0.05$) than between 5-6 of the other principle criteria. One might have anticipated a significant difference between men and women on loss of water quality given women's greater reliance on tank water for a range of domestic purposes, especially for laundry in addition to bathing. Results indicated equal numbers; a total of eight males and eight females in LHG and MAD citing the impact. However only women ranked this significantly higher than one other negative criterion; multiple-use conflicts indicating this was the most important externality faced by women.

Given the markedly different outcomes in the different villages in addition to the main effects described above one might also expect a degree of inter-action between some or all of the four background variables and the indicator criteria. However as discussed in Murray *et al.* (2004), running pair-wise comparisons on sub-data sets broken down by all permutations of the background variables is both relatively crude and time consuming. The method is therefore unsuited to searching for higher order interactions in factorial experimental designs.

Log-linear analysis is a statistical technique with potential to address such problems. The method, described in Chapter 3, is a multi-way frequency analysis technique comparable to the multi-factorial ANOVA, but designed for non-parametric data. Unfortunately it is unsuited to 'multiple-response variables', i.e. the indicator criteria cited and ranked in this section (i.e. where farmers were only requested to rank only the impact indicators relevant to them). Although the test might have conceivably been run just on just the top ranking indicators, without significant aggregation of the large number of impact criteria many cell frequencies would have been too low to meet the minimal requirements of the test. However, the method was used to asses the 'future impacts' component in the following and final section of the PIM survey

6.3.4 Future impacts

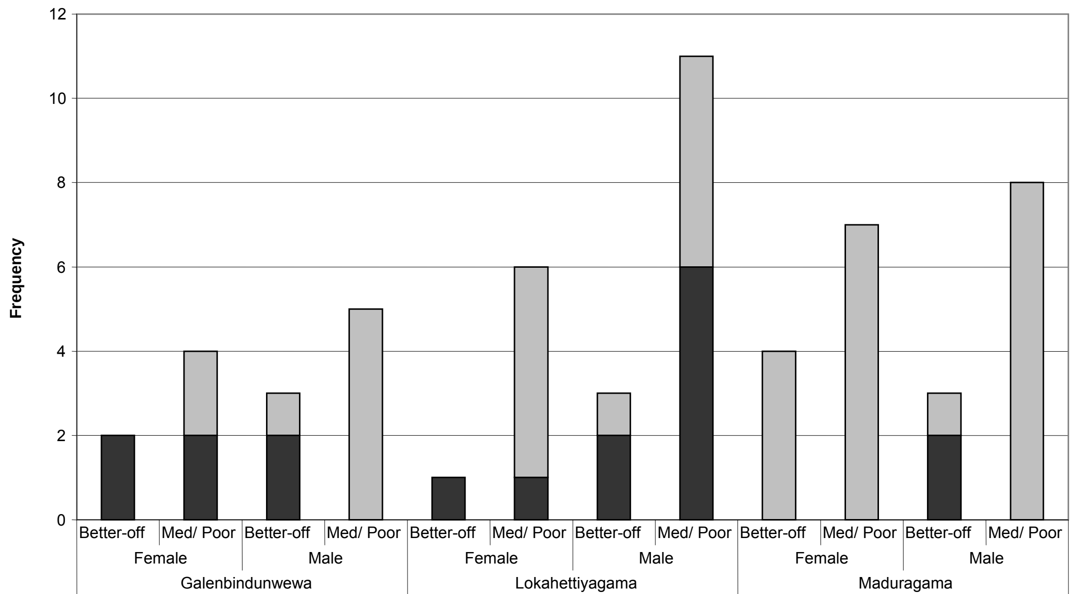
Log-linear analysis was used to investigate the relationship between the response to the question 'would you repeat the intervention?' and several (n) background variables envisaged as having potential to influence this response. Due to restrictions relating to sample size, several variables were first recoded or 'collapsed' to produce the dichotomous criteria shown in Table 6.7.

Table 6.7 Data aggregation for the principle and background factors prior to Log linear analysis (n = 57)

Factor	Criteria	Recoded criteria	N Recoded criteria
Repeat Intervention?	No	No	2
	Conditional/Indifferent		
	Yes	Yes	
Village	Maduragama	Unchanged	3
	Lokahettiyagama		
	Galenbindunewewa		
Wealth	Better-off	Better-off	2
	Medium	Medium / Poor	
	Poor		
Gender	Male	Unchanged	2
	Female		
Km to Tank	Continuous variable	≤ 0.5km	2
		> 0.5km	
Age of respondent	Continuous variable	< 40	2
		≥ 40	

Five respondents from LHG and one from MAD recorded conditional responses to the ‘repeat intervention?’ question stipulating future stocking should be contingent only on the introduction of improved mechanisms for the enforcement of rules; preferably in the form of external co-management. Three of these respondents came from the better-off wealth group and two from the poor group. Conditional responses were conservatively recoded as ‘no’ responses as indicated (Table 6.7). Only one better-off respondent in LHG expressed complete indifference and was also recoded as a ‘no’ response. An additional grouping variable not considered in the previous analysis; ‘Km to tank’ was also included under the hypothesis that households located nearer to the tanks would be more likely to participate in fishing activities.

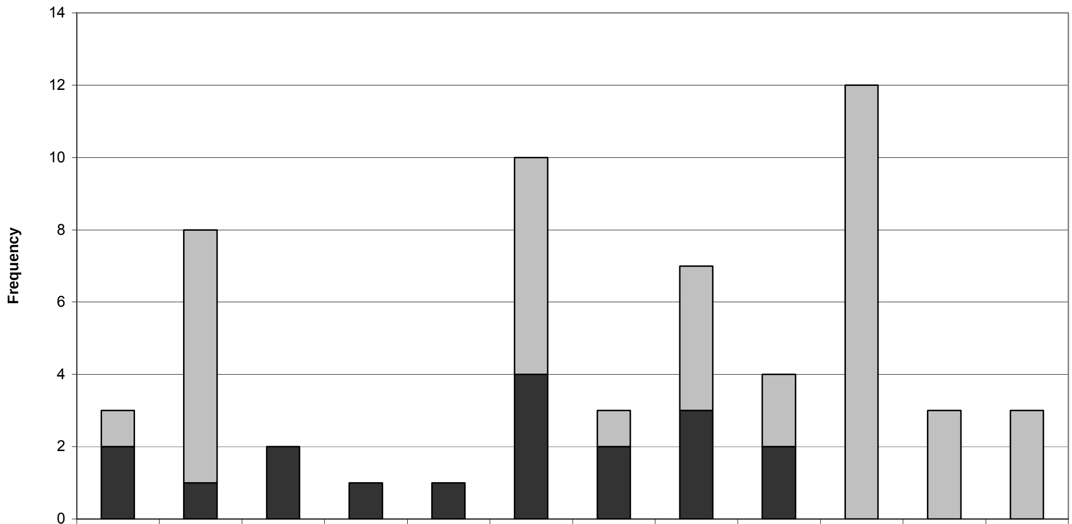
Results indicated that 68.4% of all respondents wished to repeat stocking while 31.6% did not (inclusive of conditional / indifferent cases). A high order of consensus was observed in MAD where 90.9% of respondents answered positively. Only two better-off males responded negatively; one of them conditionally (see above), while the other cited a negative bathing externality. This compared to only 57.1% and 52.4% positive responses in GBW and LHG respectively (Figure 6.31). Because of this clearly broad consensus, MAD was excluded from the following analyses.



	Galenbindunwewa Female Better-off	Galenbindunwewa Female Med/ Poor	Galenbindunwewa Male Better-off	Galenbindunwewa Male Med/ Poor	Lokahettiyagama Female Better-off	Lokahettiyagama Female Med/ Poor	Lokahettiyagama Male Better-off	Lokahettiyagama Male Med/ Poor	Maduragama Female Better-off	Maduragama Female Med/ Poor	Maduragama Male Better-off	Maduragama Male Med/ Poor
Yes		2	1	5		5	1	5	4	7	1	8
No	2	2	2		1	1	2	6			2	

Figure 6.31 Histogram and frequency tabulation for ‘repeat intervention?’ cross-tabulated against; village, gender and wealth rank background factors

The sample size (n = 57) was insufficient to run log-linear analysis on all factors simultaneously while maintaining the minimum expected cell frequency criteria described above. Consequently, the analysis was repeated for factors divided into the various groups described below. While this reduced the ability to detect higher order interactions, factor groupings were based on *a priori* expectations and the iterative outcome of successive tests. Cross-tabulations of these different groupings are shown in Figures Figure 6.31 and Figure 6.32, to illustrate the outcomes of the log-linear models.



	Galenbindunwewa				Lokahettiyagama				Maduragama			
	< 40yrs		≥ 40yrs		< 40yrs		≥ 40yrs		< 40yrs		≥ 40yrs	
	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor
Yes	1	7				6	1	4	2	12	3	3
No	2	1	2	1	1	4	2	3	2			

Figure 6.32 Histogram and frequency tabulation for 'repeat intervention?' cross-tabulated against; village, age class and wealth rank background factors

Three background factors: village, gender and wealth rank were considered in the first test. The interactions with least effect (i.e. smallest χ^2 change and largest p-value) are eliminated at each stage of the hierarchical elimination process. Criteria in the final 'best model', i.e. the unsaturated model retaining only those components which can not be removed without appreciably affecting the estimation accuracy of expected frequencies assuming total independence all have probabilities < 0.5. Finally the goodness of fit between the observed and expected values as estimated by the final model is tested. In this case it is just significant at the 0.05% level (LR χ^2 (6) = 10.41: p = 0.11 - Appendix 36: Table A36.1). The model indicates no significant three or

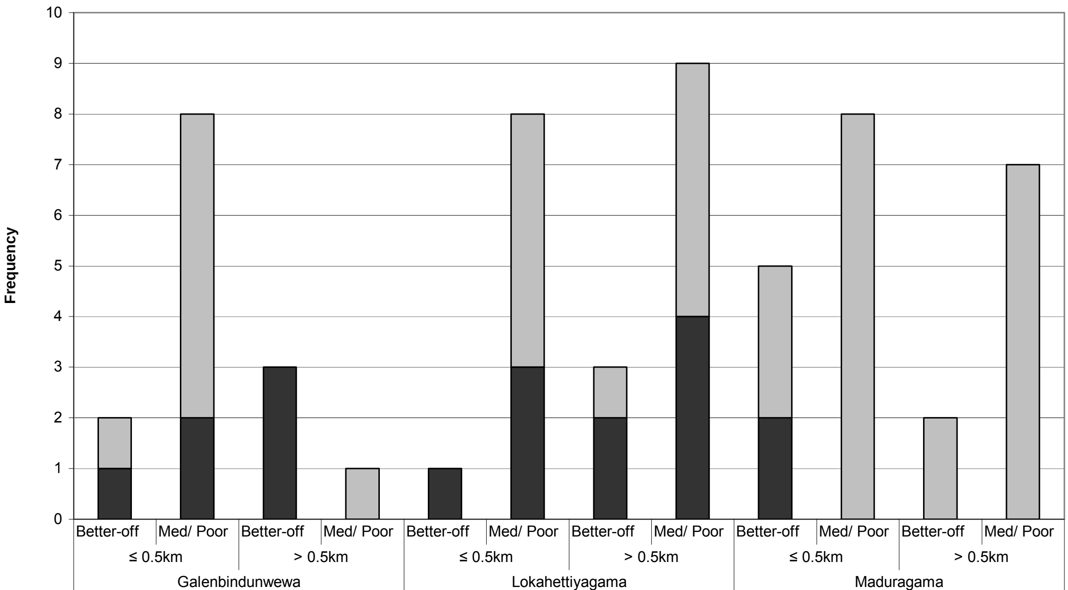
two-way interaction effects and only one significant main effect for wealth, i.e. better-off respondents in LHG and GBW were more likely to reject future stocking.
One other main effect term; gender, was eliminated in the previous iterative step (LR χ^2 (1) = 2.34: p = 0.13), falling just above the 0.05 significance level required for retention in the elimination process. Figure 6.31 shows that all better-off females in LHG and GBW (n =3) and four out of six better-off males responded negatively. While five medium / poor females in LHG (n = 6) and equal numbers in GBW (n = 4) responded positively, only in LHG did a large number of poor / medium males respond negatively (6 of 11 respondents). This anomalous situation contributed to the generally weak associations found in the log-linear analysis.

In the second model, 'village' (GBW and LHG) and 'age class' were included as the new grouping variables while 'wealth rank', which proved significant in the first analysis, was also retained (Figure 6.32). The 'best model' (Appendix 36: Table A36.2) shows a highly significant fit (LR χ^2 (6) = 1.61: p = 0.95), but there are no significant interaction terms and only one main effect term; again for wealth rank. The age class main term was removed only in the last iterative step (LR χ^2 (1) 2.34: p = 0.13). Village*age class (LR χ^2 (1) = 2.57: p = 0.11) and wealth*age class (LR χ^2 (1) = 1.72: p = 0.19) interactions removed in previous steps were also close to the retention threshold.

Figure 6.32 shows that in GBW all respondents aged 40 years or above (n = 3) responded negatively regardless of wealth, while only one of the poorer respondents aged below 40 years (n = 6) responded negatively compared to two thirds of better-off respondents (n = 3) in the same group. This suggests that in this village poorer households were more likely to continue fishing regardless of age. In LHG only one 'younger' better-off household (n = 4) supported re-stocking, while medium / poor respondents in both age groups were equivocal in there response (with 3:7 ≥ 40yrs and 4:10 < 40yrs responding negatively).

In Maduragama (excluded from the analysis), both better-off 'negative' respondents were aged below 40yrs, while all respondents ≥ 40yrs responded positively regardless of wealth status. Once again, this reflects the lower polarisation of social status in this the lowest caste village.

In the third and final analysis, ‘village’ (LGH and GBW) and ‘wealth’ were again retained, while ‘km from tank’ (distance of the respondent household to nearest stocked tank) was introduced as the third background factor (Figure 6.33). The final model (Appendix 36: Table A35.3) just reached significance (LR χ^2 (6) = 1.72: p = 0.053), again with wealth rank emerging as the only significant (main) effect. The three second order interaction effects: village*wealth, village*km to tank, wealth*km to tank, achieved LR χ^2 probabilities of 0.035, 0.52 and 0.091 respectively after the first hierarchical elimination of the single third order interaction. The weak fit of the final model was due to these high probability levels, close to but not falling below the retention cut-off point (p = 0.5). The main effect ‘km from tank’ was eventually eliminated with a relatively high probability (LR χ^2 (6) = 0.257: p = 0.61). No clear association between ‘km from tank’ and future intervention response therefore emerges from the analysis.



	Galenbindunwewa				Lokahettiyagama				Maduragama			
	≤ 0.5km		> 0.5km		≤ 0.5km		> 0.5km		≤ 0.5km		> 0.5km	
	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor	Better-off	Med/ Poor
Yes	1	6		1		5	1	5	3	8	2	7
No	1	2	3		1	3	2	4	2			

Figure 6.33 Histogram and frequency tabulation for ‘repeat intervention?’ cross-tabulated against; village, km to tank and wealth rank background factors

The earlier PIM results suggested stronger associations with the background variables which were not reproduced in this analysis. This is probably due to the fact that unless respondents were severely inconvenienced, for instance by persistent water quality externalities or hierarchical threats, they were unwilling to deny potential future benefits to other participating villagers, perhaps expecting indirect benefits for themselves. For example, many older respondents who had ceased fishing still shared the opinion that stocking should repeated for the benefit of other villagers. Several of these participants expressed a religious moral dilemma regarding the killing of fish, but averred that the food security of others was more important.

6.4 Comparison of different survey techniques

In this section I compare the three main intervention monitoring techniques employed: (1) direct observation / key informant reports reported in Chapter 5 and the (2) longitudinal household livelihood survey technique and (3) PIM surveys reported in this chapter.

The surveys were for the most part highly complementary. For example while losses due to external participation were most successfully enumerated in the observational survey, the reciprocal benefits of fishing in non-intervention tanks were more readily captured in the panel survey. The observational survey was also much more effective in exposing the operation of social taboos on fishing practices, while the PIM survey was essential for assessing post-trial participant perceptions in order to assess sustainability. Nevertheless, each method incorporated overlapping measures of participation and production, the results of which are compared below.

While all sampled households appeared to report food consumption patterns openly, there was often greater reluctance to divulge information regarding household participation in subsistence fishing. Under-reporting as a result of this cultural sensitivity compounded by a reluctance to disclose details of ‘poaching’ activity, proved a much greater problem in LHG and also to a lesser extent GBW. These sources of error were less significant in lower-caste MAD where low-caste villagers were more open regarding this activity. As might be expected, due to uncertain coverage, results from the direct observation techniques generally proved most conservative, while the longitudinal household questionnaire (which was probably most inclusive) consistently produced the highest estimates. Results of the PIM survey were more erratic compared to results from the other two surveys.

Despite this variability, MAD recorded the highest area yield levels in all three surveys. This ranged from185.5 kg ha^{-1} yr^{-1} (combined results from LUN and KRB tanks) in survey (1), to 695 kg ha^{-1} yr^{-1} in survey (2), i.e. a difference in magnitude of 3.7 (Table 6.8) with an intermediate estimate of 452 kg ha^{-1} yr^{-1} in the PIM survey. Estimates from all surveys were consistently lowest In LHG, ranging from 12.4 – 49.4 kg ha^{-1} yr^{-1}, while in GBW; survey (2) produced an estimate 5.8 times greater than the next highest result from survey (1). This was the single largest difference between any of the estimates relating to an individual tank.

Table 6.8 Summary of estimated annual area yields at 50% FSL from phase 1 and 2 intervention tanks using different monitoring techniques, Dec 00 – Nov 01

Intervention Tank	Phase	Area at 50% FSL	Yield estimate (kg ha^{-1} yr^{-1})		
			1. Direct observation[1]	2. Fortnightly household / panel questionnaire	3. PIM survey
GUR[t]	1	12.95	23.1		
IMK[t]	1	9.05	48.7		
IMK - SER[t]	1	1.75	78.6		
IMK – SER[t]	2		111.1		
GBW[t]	2	4.21	59	342	19.5
LHG[t]	2	6.78	15.4	49.4	12.4
MAD – LUN[t]	2	1.9	100.7	695	171
MAD – KBW[t]	2	0.95	84.6		281.1

[1] Compiled from researcher and participant recording systems (chapter 5)

Which of the techniques then, was able to give the most reliable estimates of such temporally dispersed staggered harvesting activity? All respondents who had participated in the two surveys based on recall, i.e. the longitudinal and PIM surveys, answered more conservatively in the latter survey. Indeed, three households in GBW and two in LHG who reported fishing-participation or consumption of local tank fish in the first survey failed to acknowledge this entirely in the subsequent PIM survey. Unlike the PIM survey, the household questionnaire also solicited information on subsistence fishing activity indirectly, thereby overcoming some of the sensitivity associated with the issue, i.e. respondents were asked about the range of all fish and fish substitutes consumed before being questioned about price and source etc.

Consequently, the most reliable lower and upper production estimates are likely to have come from the direct observation and structured household survey techniques respectively. Both these surveys were based on frequent recurrent visits and were therefore less subject to failing recall. However the household survey also captured much higher rates of participation consistent with its higher yield estimates (section 6.3.1) and there appears to give the most reliable yield estimate.

Despite these differences, all the surveys demonstrated highly consistent seasonal production trends. A minor difference in the major production peak; August and September in surveys (1) and (2) respectively, was due to the fact that a large amount of collective fishing took place at the end of August wasn't reported in survey (2) until early September. The household questionnaire alone captured the low-level fishing activity in April and November, i.e. at the beginning and end of the trials.

A final question relates to the appropriateness of each method in terms of resource requirements. In order to improve efficiency and avoid unnecessary burden on participants Chambers (1994a) advocates 'appropriate imprecision' in the selection of appropriate data collection techniques. Although panel type surveys are considerably more resource intensive in terms of data collection and management than either of the other two techniques, the use of all three is justified in the context of interventions based on common property resources where interactions between multiple stakeholders are likely to be highly complex and spread over an extended period of time.

6.5 Summary

In conclusion overall results indicate that MAD was the most successful of the three intervention sites, both in terms of production levels and the equitable and relatively conflict free manner in which these yields were distributed. Furthermore, the PIM survey indicated that only in MAD did villagers perceive sufficient gain for there to be a strong likelihood of sustainable adoption. This was despite the fact that the smallest and most highly seasonal water bodies were also stocked in MAD.

This outcome was a consequence of several factors including the strategic location and small-size of the tanks which deterred free-riding and optimal stocking levels and species combinations. However, this was also the only village where there was sufficient pre-intervention social cohesion and institutional capacity to effectively manage staggered harvesting. This underscores how significant these social factors are to collective management outcomes. Their subordination to bio-technical considerations is one of the main causes for the repeated failure of conventional stocking interventions.

Chapter 7 Summary: impacts on the livelihoods of the poor

7.1 Introduction

The main objective of this study was to develop low-input fisheries enhancement strategies in seasonal village tanks of the Dry-Zone of Sri Lanka through a process of action research and to assess how they might benefit poorer groups. First thirteen cascades located over a wide geographical area in North West, North Central and Central Provinces were assessed using a rapid screening process informed by a preliminary situation analysis. In depth research was subsequently carried out in 14 watersheds containing 120 tanks, in Puttalam and Kurunegala Districts, North West Province between 1999 and 2002.

Preliminary farmer-managed trials took place with three communities (5 Tanks) in 2000. A second phase of modified trials took place with three new communities and one old (5 Tanks) in 2000/01. A concurrent fortnightly household livelihood monitoring survey incorporated a total of 41 wealth stratified households in four low-caste communities in a range of watershed locations. This was implemented over a year and commenced with a detailed baseline survey and wealth ranking. A detailed longitudinal assessment of fish yields was implemented over the same period, as were two other surveys investigating tank nutrient dynamics (5 tanks) and tank topography / hydrology (8 tanks) which are reported elsewhere. A detailed questionnaire assessing the agricultural cropping strategies of the 41 monitoring households and a participatory impact monitoring (PIM) questionnaire investigating farmer perceptions towards the trial outcomes were also undertaken upon completion of the second trial phase.

7.2 Community-managed water bodies as a focus for development

Extensive areas of the Asian sub-continent that have erratic bimodal rainfall patterns can be characterised as ‘water stressed’. The traditional response by local people has been to construct rainfall-harvesting systems to allow supplementary irrigation of their crops. Such water bodies range in size from less than one to tens of hectares; larger 'perennial' systems will contain water all year, whilst in some years smaller 'seasonal' systems will empty completely during the driest months. These rainfed systems receive water only from their own micro-catchments as opposed to the trans-basin diversions and more assured irrigation regimes characteristic of large-scale reservoirs.

Small village ponds, also known as '*tanks*' in India and Sri Lanka, became a traditional focus for settlement and have multiple roles in village life. Management of these systems was for the most part undertaken by village communities themselves. In both Southern India and Sri Lanka the nature of the land meant that small tanks were typically constructed in a cascading sequence within micro-catchments. This resulted in greater efficiency in water use in the watershed as whole, and with careful management, flooding, siltation and soil erosion was reduced. Linkages of water bodies in the same watershed also called for some degree of inter-community cooperation; neglect and breach of the bund in an upper tank could cause damage to tanks and lands below, whilst changes in storage capacity in one part of the watershed can affect availability elsewhere.

Post-Independence, traditional village management institutions were replaced with 'farmer organisations' imposed by central government via the Department of Agrarian Services charged with agricultural extension. This attempt to nationalise such a widely dispersed micro-resource proved ineffectual with state institutions having neither the resources nor the capacity required to take responsibility for their maintenance. This policy along with environmental and social pressures resulting from increased population and demand for water, have had negative consequences for the sustainable management of village irrigation systems.

Typically the development focus of seasonal water bodies has been biased towards their role as irrigation storage rather than as multi-use resources; interventions have been at the household level or based on over-simplistic definitions of community as homogeneous units, i.e. 'One village, one tank'. Consequently, attempts to enhance fish production have been constrained due to poor understanding in two key areas (1) the appropriate time and spatial scales at which aquatic and related agricultural production systems work (2) the *de facto* nature of access arrangements by different stakeholder groups to common property resources including seasonal water bodies.

7.3 Multiple-use characteristics of seasonal tanks

The potential value of seasonal water bodies for a range of uses is a function of their size, the duration for which water is retained and the quality of water. These factors are heavily influenced by their position in the watershed. Tanks have multiple-uses, both in terms of (1) the water they store and (2) their physical structure. Priorities for tank use in order of importance are:

- *Irrigation* of paddy (supplementing rainfall) remains the main priority for most community members but the increasing importance of off-farm labour has reduced its relative importance compared to other uses. Many farmers no longer risk supplementary irrigation in poor rainfall years preferring to work off-farm to generate cash.
- *Bathing,* partly as a result of a decline in paddy cultivation has increased relatively as a priority role of tanks. In addition to its practical function, bathing serves an important social role.
- *Livestock watering* is the next most important overall use though this is influenced by an already low and decreasing trend of animal numbers resulting from losses of pasture, increasing farm mechanisation and increased reliance on off-farm labour opportunities as elsewhere in Asia.
- *Aquatic production* currently has a relatively low priority, although it is more important for poorer members of the community.
- *Indirect benefits* such as ground water recharge, flood control and impacts such as the potential role of tank enlargement in shifting water deficits downstream were very poorly perceived by farmers compared to the activities bringing direct individual benefits described above.

Negative externalities associated with these different uses are most acute in smaller seasonal tanks. Conversely, decision making and conflict resolution are simplified due to the involvement of fewer stakeholders. As a relatively low priority use, fishing is subordinated to the two most important uses; irrigation and bathing. A common perception held by farmers; that fish activity which involves entry into the tank can increase percolation losses, is a regular source of conflict between different water users. However, seasonal hydrological profiles presented in Murray (2004b) suggest that such fears are largely unfounded and are in some instances used to perpetuate control of the resource by village elites (Chapter 5). Conversely, intensive fishing activity during the dry season does lead to brief but dramatic increases in water turbidity and conflicts with the majority of villagers who rely on the tanks for bathing. Whether real or perceived these factors must be considered during the implementation of stocking interventions.

7.4 Demand for inland fish

Freshwater fish, especially tilapias, constitute the major source animal protein for poor people in the Dry-Zone. Preference ranking results (Murray *et al*. 2004) demonstrated that while inland fish were overall the most popular food type, both larger inland and marine fish were more popular than small sizes of the same varieties (<150g - 175g). However despite such preferences poorer people mostly consume small tilapia because of their low cost and freshness. The commercial demand for fish caught from seasonal tanks is relatively low, however, and the current priority accorded to exploiting fish from these water bodies is correspondingly low. This situation is explained by the following factors:

- *Substitutes:* Low cost and high availability of fresh tilapia from nearby perennial tank fisheries
- *Off-flavours:* Negative consumer perceptions regarding muddy / soapy off-flavours associated with tilapia from highly seasonal tanks
- *Multiple-use priorities:* Multi-purpose use of tanks and fishing as a cause of social conflicts; particularly with irrigation and bathing uses.
- *Structural changes:* Increased reliance on agricultural labour and other off-farm income generating activities in peoples' livelihoods have reduced reliance on the natural resource base in rainfed areas.
- *Erratic availability:* Inconsistent yields related to seasonality in water availability and undeveloped methods of harvest. Conservative fishing methods related to religious and cultural beliefs are inefficient.

- *Low status:* Whereas participation in perennial artisanal fisheries has achieved a degree of acceptability amongst different social groups, subsistence exploitation of fish from seasonal tanks remains a low status activity often undertaken by the poorest and most marginalised people.

By contrast, the harvest and trading of freshwater fish caught from large perennial tanks, particularly tilapias that dominate production, is important to the livelihoods of large numbers of rural people. The proximity to the perennial tanks allows large numbers of bicycle vendors to trade small quantities of freshly caught fish between artisanal fishers and dispersed communities throughout the rainfed areas. The costs to entering trading networks are low, the fish sold (without ice) are very fresh and benefits well distributed. Fish from seasonal tanks do not enter this marketing chain in significant quantity, mainly for the reasons given above.

In Sri Lanka, much of the debate surrounding enhancements has become polarised over the role of tilapias and exotic carps. As in India, advocates of exotic carps cite their higher value and marketability. Yet little evidence has been put forward regarding the extent to which premium prices could be sustained if production was significantly increased. Our results, (Murray 2004a) indicate a relatively low preference for carps *per se;* instead their current popularity appears to be part of an unfulfilled niche for larger-sized fish in general.

7.4.1 Policy implications

Because of the fundamental role of inland fisheries in rural livelihood security, in this sector at least, equitable distribution should be prioritised above macro-level economic growth. Consequently, plans to increase commoditisation of inland fish by promoting inland fish consumption amongst better-off urban consumers (where negligible demand currently exists) and export markets (MOFARD 1995, ADB 2002) are cause for concern. A similar market study was undertaken in Northern Karnataka state, India (Murray and Felsing 1998) where the Government has promoted culture-based carp production systems designed to yield larger, high value fish. This has resulted in over 70% of local production being exported to distant urban markets with established demand for larger inland fish. Consequently, small-scale rural vendor networks hardly exist, rural producers receive on average 25% or less of the final retail price compared to 50% or more in Sri Lanka and rural *per capita* consumption rates average less than 2.5 kg per *annum* compared to more than 15.5 - 17.5kg in the current study. Thus far, the Sri Lankan tilapia fishery and its local market networks have proved extremely resistant to such change.

7.5 The nature of seasonal tanks and implications for aquatic production

Smaller tanks, that are more likely to dry out completely, exist at the top of watershed. This has implications for many of their uses, but especially for irrigation and fish production. Larger tanks lower in the basin receive water from a greater proportion of the watershed and tend to have perennial water. Seasonal tanks can be defined as 'radial' or 'axial' depending on their position in the watershed.

Radial tanks are located in upper-watershed areas where they rely only on rainfall falling into their own micro-catchments. They are the smallest (<1-5ha), shallowest (<1.5m) and the most seasonal water bodies (completely drying more than once every 5yrs), but also the most numerous irrigation resources. Many remain unquantified due to their relative physical inaccessibility; uncharted, mostly small radial tanks represented 47% of the 120 tanks mapped in the current survey. Axial Tanks also receive drainage and spill waters from radial or other axial tanks further up the watershed. Seasonality, depth and area increase with progression down watersheds. Larger axial tanks in mid- and lower-watershed locations tend to be semi- seasonal or perennial (Figure 7.1).

Figure 7.1 Classification of tanks based on natural fishery potential

Seasonality class	Seasonality (and fish survival) characteristics	Spatial characteristics
Highly seasonal	Completely dry every year with complete loss of fish stocks	<0.5-5ha, mostly radial or axial 1
Semi-seasonal	Completely dry more than once every 5 years	1.5-14ha, mostly radial or axial 1
Periodic-seasonal	Completely dry at least once every 5 years	2-20ha, mostly axial 1 or higher
Perennial	Has not dried in living memory (other then for rehabilitation purposes)	>8ha, mostly axial 2 or higher

One of the main findings of the hydrological survey (Murray 2004b) was the rapid rate with which stored water is lost from shallow village tanks as a result of percolation and evaporation early in the storage cycle. Consequently, it is rational for farmers to 'use or lose' water for irrigation early in the season while conservation measures should focus on maintaining dry season residual storage for bathing, livestock watering and fish production etc.

Farmers often characterise seasonality according to their primary water use, i.e. irrigation. Accordingly they may classify tanks as being 'dry' even when sufficient dead storage remains for bathing, use by livestock and to allow fish stocks to survive. A variety of factors, including increased off-farm labour opportunities, has led farmers to be less inclined to risk water use for supplementary irrigation and to maintain water levels in the tank for other purposes. This may favour their potential for fish production.

The volume and duration of water storage in seasonal tanks determines whether sufficient fish stocks persist from one rainy season to the next. Potential carry over of stocks allows re-colonisation of the same tank and, after migration upstream, re-colonisation of other tanks higher in the watershed as described below.

In addition to their seasonality, the filling and over-spilling of the tanks is a critical feature for natural fish production in these 'cascading' tanks systems. Successive tanks in a cascade sequence are intermittently linked by spill events and their frequency, duration and sequence determines the potential for fish migration / natural recruitment in upper seasonal tanks following years in which they have completely dried out. Most spill events take place during the main NW monsoon. In average and below average rainfall years, they are less common. Although smaller tanks tend to spill more frequently and for shorter periods than larger tanks, where adhered to, Irrigation Department tank design criteria should cause events to commence almost simultaneously. In reality construction and rehabilitation efforts are rarely co-ordinated at the watershed level resulting in discontinuities in the sequence of spill events. A sequence whereby smaller upper-watershed tanks complete spilling prior to onset in lower perennial tanks will have the most adverse consequences for upstream fish migration.

The frequency of spill events has been further reduced by increased levels of impoundment within watersheds during tank repair and construction programmes over recent decades. The same design criteria should result in most tanks spilling with an average frequency of nearly three out of every four *maha* seasons. However, during this study major events, capable of triggering mass migrations, i.e. simultaneously linking all the tanks in the cascade, were found to occur only once every 4-5 years. To place this in context, conditions for natural repopulation still appear much more favourable in Sri Lanka than in neighbouring Tamil Nadu with its similarly extensive tank resource but lower annual rainfall levels. Based on 40 years of rainfall data (Palinasami *et al.* 1997) found that a sample of cascade tanks in eight districts of Tamil Nadu State, India experienced deficit supply in 5 of 10 years, in 3 years the tanks will fail, in one year they will have full supply and surplus storage in only one of every 10 years.

A frequently cited justification for stocking enhancements in seasonal tanks is that they are nutrient rich and therefore high potential systems. Watersheds act as sinks for nutrients; shallow tank beds result in frequent exposure and remineralisation of sediments ensuring that nutrients remain available to natural food webs that support fish stocks. The rapid filling of the tanks once rains begin favour fast growing species feeding at the base of the food chain as food is plentiful.

However rates of nutrient availability are more important than absolute levels and results show that water quality conditions in these systems are in fact seasonally hyper-variable (Murray 2004b). Conditions range from mesotrophic to hypertrophic over the course of the year and are most extreme in smaller highly seasonal tanks as a result of dilution and concentration effects. Low phosphate levels limit primary productivity at inundation as a result of adsorption to inorganic turbidity and dilution and juvenile fish stocks should be stocked prior to or after this period. Stocking fast growing juveniles immediately after inundation may reduce some predation related mortality but will also reduce the grow-out window in highly seasonal tanks. Extremes in inter-related physical parameters as well as inorganic turbidity are also likely to check growth as water levels reach dead storage levels, especially in smaller tanks.

These trends are also complicated by an alternation between stable macrophyte / periphyton and phytoplankton dominated states (Murray 2004b). This shift is also driven by seasonal fluctuations in water level and is therefore likely to recur each year in highly seasonal tanks. However, because the shift will occur over a wide range of nutrient concentrations, transitions will be inherently chaotic and therefore much less predictable in intermediate sized tanks. This has great significance for fishery management as the two states provide very different habitat / nutrient conditions with implications for the selection of suitable fish varieties as well as on the efficiency and likely deployment of different fishing gears. A further consequence of these findings is that smaller seasonal tanks are likely to be more dependent on regular external inputs for P and other nutrients than larger perennial systems.

The interplay of all these highly stochastic production factors is responsible for persistently weak empirical correlations between stocking density and yield outcomes (Chapter 1). Yields of resident fish stocks are erratic for the same reasons. If tanks completely dry out and fish stocks disappear, productivity is reduced until repopulation can occur, normally through migration upstream during spill events. Thus a combination of climatic factors, catchment characteristics, the nature seasonal of water availability (hydrological endowment) at the individual tank and cascade level, and farmer irrigation responses to the hydrological factors affect productivity. The replacement of traditional earthen surplus weirs with more durable concrete structures also presents an increasingly significant impediment to upstream migration and repopulation of seasonal tanks. The net result is that most smaller radial tanks (<2ha), lose their entire fish population on average once every five years and have sub-optimal production in 3 of the 4 remaining years.

7.6 Settlement around, and access to, seasonal tanks

Understanding the nature of human settlement around small water bodies is as important in the identification of potential interventions favouring the poor as assessing their physical nature. Uncritical targeting and inappropriate development risks poor or negative impacts. This is critical in the context of common property resources such as village tanks where a broadening of focus from household to community is required to predict who might benefit and lose from specific interventions. I consider both the relationships of different users to the water resource and the relationships between users themselves in regard to the resource. The following are a summary of the key factors identified in developing strategies for the poor to access benefits from seasonal tanks.

7.6.1 Categorisation of social boundaries

Two principle forms of rural settlement are interspersed throughout the Dry-Zone; (1) *purana* villages and (2) irrigation colonies which have resulted from traditional and modern patterns of settlement respectively. *Purana* (old or traditional) villages predominate in rainfed areas and in inland locations they are constituted almost entirely of Sinhalese Buddhist populations, typically of uniform caste. Smaller settlements are also likely to consist of single kinship groups (*variga*). Irrigation colonies have accompanied the development of major irrigation systems aimed at relieving population pressure in the hill country over the last 30-40 years. Often the size of a small town, these colonies benefit from good physical infrastructure. They are typically populated by heterogeneous kinship groups despite some attempts to resettle entire communities. Intensified agriculture under major irrigation systems and service opportunities in their associated colonies also provide significant off-farm labour opportunities for inhabitants of *purana* villages in neighbouring rainfed areas.

I coin the term '*purana complex'* (PC) to describe groups of villages / communities with strong kinship links sharing access to components of the local natural resource base. Within PC boundaries discrete community groups of uniform ethnicity, religion, caste and often kinship access the same surrounding radial and axial tanks, and with lesser degrees of exclusivity to adjacent forests and pasturelands. Rather than the traditional household or individual tank level the PC is identified as the smallest logical watershed sub-unit for intervention in rainfed areas. A typical PC will have access to one or occasionally two or more larger axial tanks and up to as many as 20 or more seasonal radial tanks. Small upper-watershed communities typically control no more than 1 axial tank and 1-2 radial tanks, all of which tend to be highly seasonal. The size of such communities tends to be correspondingly small, typically ranging from 20-60 households. Within a community, settlement is usually most concentrated around the largest axial 'base' tank.

The oldest *purana* villages tend to be established around the most reliable perennial or larger semi-seasonal (non-system) tanks in lower and mid-watershed areas. Traditionally farmers from these villages extended irrigated cultivation to smaller seasonal radial tanks adjacent to their base tanks, often on a rotational basis. Increasing population pressure has resulted in progressive settlement around smaller radial tanks. Frequently ownership of much of the irrigated land, and control of the water in such radial tanks, continues to reside with more affluent older farmers around the base-tanks causing inter-generational conflicts. PCs in the uppermost reaches of watersheds are distinguishable by their lower wealth status relative to lower-watershed communities. This marginalisation is a consequence of the highly seasonal nature of their tanks, poor physical infrastructure and their frequently low-caste status. Upper-watershed areas are also often buffer zones between productive agricultural land and forest/shrub and prone to conflict between people and large wildlife.

A PC may cover the whole or, more commonly, part of a catchment, depending on the catchment size and hydrological endowment. The number of larger axial tanks is often indicative of the number of PCs within a micro-watershed. Occasionally PCs extend to radial tanks in neighbouring watersheds, but more often are delineated by natural catchment boundaries. The smaller size of communities in the upper watershed generally simplifies collective management of tanks. However, water shortage is more likely in these areas, necessitating intensive multiple purpose use in fewer, smaller tanks, i.e. there is both a greater need and potential for collective action in these locations.

The range of formal institutions in *purana* villages is limited. Externally constituted institutions including farmer's organisations responsible for irrigation decisions tend to be unrepresentative of the village as a whole and tend to be dominated by better-off households with most land. The most active and inclusive village institution identified was the Death Donation Society (DDS); indigenous community welfare groups that manage micro-credit for the observance of costly funeral rituals. They are also widespread, constitutional and democratic, include even the poorest households, hold regular, well documented meetings and have clear, sanctionable rules. When membership of community- based institutions extends across PC boundaries it is frequently linked to inter-community leasehold / ownership of paddy lands.

Membership of a neighbouring Death Donation society may indicate kinship linkage or poor social cohesion within the native PC.

7.6.2 Access to tank fisheries:

Marginal upper-watershed communities exhibit greatest reliance on the natural resource base, including fisheries, for subsistence, largely because of a lack of alternative livelihood strategies. This often includes exploitation of tanks lower in the catchment with more perennial water, where fisheries are of less significance to the higher-caste groups that live there.

Regular ‘staggered’ harvesting is most commonly practiced using hook and line fishing gears for three reasons: (1) hook and line is more affordable than nets (2) it is most efficient under the conditions which follow shortly after the tanks fill, i.e. turbidity levels decrease and smaller / shallower tanks become heavily encroached by aquatic macrophytes (3) as the method has a minimal requirement for entry into the tank, there is less risk of conflict with alternative water users. Consequently, such low level ‘poaching’ is generally well tolerated. Indeed there may be various degrees of reciprocity; ‘poachers’ will often be invited by friends in neighbouring villages, especially if they own nets. More intensive collective fishing events traditionally took place at two main times during the year (1) during spill events as rainfall peaks and (2) just prior to total drying out of smaller seasonal tanks. Dry season collective fishing is a shared social event with members of neighbouring villages. Where larger water residuals persist, the participation of external fishers who bring their own gears can be a cost effective way of increasing fishing efficiency for all participants. Whether or not net benefits accrue to the host community will depend on local capacity to regulate access while avoiding conflicts and without prejudicing reciprocal access to external tanks.

Findings presented in Chapter 6 demonstrated how access to tanks with a variable range of sizes and corresponding seasonality extended availability of subsistence production to the poorest groups over the year; excluding only December and January. This incorporated substantial production from smaller tanks between 1.5-4ha by virtue of their high CPUE levels and cumulative ‘staggered’ yields. Consequently, a significant proportion of the catch consumed by poor households came from subsistence fishing in external tanks, i.e. outwith their PC. Low-level fishing of this kind is often tolerated or, as indicated above, reciprocated on an informal basis.

This suggests the most important thing that can be done to help the poor is to develop or sustain strategies to maintain their access to tanks outside their community. This also implies that promotion of more intensive forms of aquaculture would allow wealthier groups to exclude the poorest. This has been an unfortunate by-product of aquaculture development in Bangladesh and elsewhere (O'Riordan 1993). In Sri Lanka, external attempts to promote stocking have largely ignored these subtle, informal access relationships; marginal groups designated as poachers are ignored or excluded and interventions ultimately overwhelmed by conflicts. The extent of this problem has been masked by seed constraints which typically limit stocking initiatives to one, occasionally two year cycles before subsidies are withdrawn. However, the formalisation of access rights is also difficult to negotiate between communities, especially if caste identities are strong and polarised. Promoting co-management between communities is likely to be problematic for these reasons.

Whereas caste and kinship are the principle characteristics demarcating inter-community access, intra-community access is conditioned primarily by wealth, gender and age. Buddhist religious belief and cultural norms mean that older people (>40 years) tend to be less involved in active fishing and tend to consume less fish from local tanks. Instead younger, poorer people, especially those from low-caste upper-watershed communities are most dependent on fish from seasonal tanks. This group is most likely to engage in staggered harvesting, principally using hook and line, throughout the season. Sinhalese women are excluded from any participation in harvesting fish but do receive a share of the catch if male members of the household or extended family participate. Fishing in seasonal tanks is also often undertaken as a male social activity involving alcohol consumption. This tends to increase women's aversion to male participation after marriage.

In the past collective fishing was formally organised through village institutions, normally with at least several days notice of intent prior to the event. This allowed each household within the village to organise either participation or at least male representation at the tank side to ensure their share. Over recent decades collective fishing events in seasonal tanks have become less formalised. Most are now finally triggered by a progressive increase in unsanctioned fishing with nets as water levels fall. The lack of prior knowledge which this entails has several consequences: (1) female headed households, and those with males involved in off-farm labour are likely to lose share (2) Knowledge and participation in the event is limited only to the local and most immediate neighbouring communities (3) without forehand knowledge, bicycle vendors are less likely to be present to purchase surplus catches (especially of valuable snakehead). These are instead usually dried for later household consumption or gifted to extended family members and neighbours.

Even when methods which create little conflict with alternative water uses are practiced conflicts associated with re-distribution of fish yields can still arise. While traditional collective harvesting techniques target the whole village, because of cultural taboos, hook and line techniques tend to discriminate against better-off households in favour of the poorest groups. This can create envy and threaten delicate power balances within existing community hierarchies.

7.7 Intervention approaches to benefit the poor

7.7.1 Rehabilitation of seasonal tanks

The conventional and most common intervention in watershed areas is tank rehabilitation, in which the storage capacity is increased through raising the height of bunds and / or deepening of the tank and permanent surplus weirs and other hydraulic structures are constructed. These measures tend to change both water availability and spill characteristics; while the period of water availability is increased both spill frequency and duration will tend to decline (section 7.5). These changes are targeted mainly to the needs of local irrigators despite having impacts on a range of water uses including fish production. In this respect, the seasonality of village tanks is also compounded by design criteria which maximise 'live-storage' for gravity-fed irrigation and often minimise dead storage. In practice, periodic excavation of material from areas below the bund for the renovation of earthworks is one of the main ways that dead storage capacity is maintained. However, the cost of such works means that extensive mechanised de-silting is more likely to be practiced in larger tanks.

Both planners and farmers have a poor perception of the impacts of these rehabilitation steps on resource flows operating upstream and downstream within the same watershed. This study demonstrated the adverse effects of de-silting on nutrient status and fish production during the following rainy season (Chapter 5). Furthermore, rather than a process which stimulates internal change and self-reliance, communities often view such repairs as a form of immediate and tangible benefit to be provided through patron-client relationships with local politicians and government agencies.

7.7.2 Fisheries interventions implications

Conventional efforts to promote aquaculture in seasonal water-bodies have focused on technical innovations, i.e. identifying what species of fish to stock, how to produce the required fingerlings and the optimal stocking strategies. Unfortunately, such efforts have not been sustainable nor delivered benefits to the poorest groups. Indeed, development interventions promoting fish production have frequently created or exacerbated conflicts within and between communities.

Enhancement based on stocking hatchery-produced, usually exotic carps has demonstrated that high, although often-inconsistent, fish yields are possible in larger village tanks. This has resulted in most sponsored interventions being based on this strategy, although there is little evidence of sustainable uptake. Technical factors, principally lack of assured seed supplies, and social factors, based on a lack of understanding of stakeholder dynamics and multiple water-use interactions, underlie the lack of success to date.

Public sector seed supply has acted to stimulate household level aquaculture in many other Asian countries, but this approach has failed in Sri Lanka. This can mainly be explained by aquaculture being uncompetitive with other farming activities, which is unsurprising given the wide availability and low cost of fish from perennial tank fisheries and the opportunity cost for highly profitable ornamental fish production for export markets in existing capital intensive hatchery facilites (Murray 2004a). If public sector fish seed production is to be revived through any substantial reinvestment, it would need to be linked to the long-term supply of seed for stocking village tanks.

Local nursing of hatchery carp fry has also been promoted successfully elsewhere in Asia as a strategy to reduce costs of seed supply from hatchery centres and ensure better survival of stocked fish. Grass roots organisations have been involved in promoting this as a community activity however there have been few examples of successful and sustained adoption. Attempts to promote this approach in Sri Lanka are also unlikely to achieve widespread adoption due to: (1) its complexity as a technical and group activity (2) the heterogeneity and stochastic production characteristics of the seasonal tank resource (3) high costs of management and uncertain returns to individual effort in the context of CPRs (4) socio-cultural barriers to inter-community cooperation necessary to achieve profitable economies of scale over the longer term.

What then are the opportunities for enhancements based on natural stocks? The unpredictable natural breeding and recruitment of natural stocks in seasonal tanks prone to the complete loss of water and breeders has been a major incentive to attempts to increase productivity through stocking with hatchery-produced seed. However, this research has shown that the nature of cascading tanks and their close proximity to large perennial fisheries offers an alternative opportunity – the transfer of adult or juvenile fish from perennial water to restock seasonal tanks at the onset of the rains.

The species and size of fish stocked, the timing of stocking, the level of predation pressure and timing and methods of harvesting are all important considerations for improving the productivity of seasonal water bodies as discussed below

Tilapias and snakehead harvested from perennial tanks within the same watershed; either as small seed using hand nets by community members, or, purchased as viable adults from traders have both been successful methods to re-establish populations of tilapias in seasonal tanks. In tanks that have completely dried out, juvenile snakehead can be stocked at the same time or slightly later to avoid subsequent stunting of the breeding tilapias. In tanks with carry over stocks of snakeheads, stocking larger tilapias, rather than small fry, is recommended. Evidence that the practice of transfer of stock within watersheds and by purchase already occurs at a low level suggests its practical viability.

The exotic snakeskin gouramy whilst typically growing to little more than 50-60g breeds and occurs in large numbers under seasonal tank conditions. The poorest groups, such as female-headed households with dependent children, appear to benefit most from this species and other small indigenous species including; climbing perch, yellow catfish, *Puntius* spp. and *Rasbora* spp. which are consumed in smaller quantities.

Low water levels are tolerated better by some fish species than others. Air-breathing predators tend to survive low water conditions more than herbivorous and omnivorous carps and tilapias. Thus stocking of small seed into tanks in which large predators remain yields inconsistent results. Conversely if tanks dry out completely and no predators remain to control the breeding of stocked tilapias and other species, 'stunting' typically occurs resulting in small, low value fish.

Once the NW monsoon rains begin, seasonal tanks tend to fill rapidly. Typically, if the water body has completely dried out there are no, or very few, fish to utilise the resource until spilling occurs and fish migrate upwards from perennial water bodies lower in the watershed. Normally communities resist stocking prior to the normal timing of spills from the tank as they perceive fish are lost in these events. Thus, re-colonisation of upper-watershed tanks, if it occurs, happens late in the season and potential productivity is lost. In some communities entrepreneurial individuals have stocked tilapias from other tanks that retain water or have even been purchased from itinerant traders selling large perennial tank fish.

Late or erratic stocking and inconsistent levels of predation pressure tend to result in yields that vary greatly in both quantity and quality from one year to another. Intermittent or 'staggered' harvest of fish from the tank is desirable both because (1) it can inform the community if the number and size of fish in the tank is at a desirable level and (2) optimise the total yield of fish that can be produced and (3) produce fish through periods when alternative sources of fish are less available or more expensive.

7.7.2.1 Introducing new practices

The widespread perception that early stocking leads to loss of fish during spill events; can be changed. Discussion of the frequency of spills, their own observations of the direction of fish movements, and the risks / costs of stocking together with explanations of the nature of yield limiting conditions can lead to improved understanding and support for early stocking and regular harvest.

An alternative strategy would involve stocking small ‘nodal’ axial tanks with the greatest number of hydrological linkages to seasonal tanks further up the watershed. This would be the most cost effective way of re-establishing self-recruiting species on a whole watershed basis after a sequence of drought years.

Results presented in Chapter 6 clearly demonstrated the benefits of frequent and intermittent ‘staggered’ harvesting; even smaller tanks between 1.5-4ha are sufficient in size to produce substantial cumulative ‘staggered’ yields by virtue of their high CPUE levels.This is already practiced to a greater or more limited extent, usually by poorer more marginal people. Community perceptions regarding the acceptability of the practice are finely tuned to the precise timing and methods adopted. Constraints to uptake include the following:

- Poor knowledge of the potential savings of cash used to purchase fish.
- Attitudes to certain types of staggered fishing; the use of worms for hook and line fishing is perceived negatively.
- Loss in perceived control by ‘better-off’ households at the top of the community hierarchy. This group is more inclined to promote traditional single collective harvest where yields can be bulked and sold for income generation and / or for raising of funds for investment in the village organisations which they control.
- Unfavourable comparison with widely piloted exotic carp stocking programmes which promise high short-term direct income benefits but which require sustained external assistance.
- Expectations that frequent harvesting activities involving tank entry will increase multiple-use conflicts with irrigators and bathers (section 7.3).

Findings presented in Chapter 6, also indicate how access to tanks with a variable range of sizes and corresponding seasonality can extend availability of fresh fish to the poorest groups (December and January were the only months when no consumption of subsistence production was recorded in any village). This also includes access to tank fisheries outwith the immediate community; often this takes place on an informal reciprocal basis or low-level fishing is tolerated as long as it does not conflict with other water uses. In the past, all those participating in such activity have been designated as ‘poachers’, without discrimination, and excluded from stocking programs on this basis. Instead, and if interventions are not to be repeatedly overwhelmed by conflicts, site specific assessments of prevailing access patterns, including the degree to which they are accommodated alongside the more formalised rules of village institutions are essential.

7.7.3 Identifying communities for interventions

The following factors should be considered in identification of communities for intervention. At the outset, geographical and social mapping techniques should be used with key informants to identify appropriate PCs rather than simply focusing on single tanks and their adjacent communities. PCs which are most appropriate for interventions tend to occur in upper-watershed areas where many of the poorest low-caste groups live. The same groups are most dependent on the extraction of a range of natural resources for their subsistence.

Having established the need for interventions, the potential for successful collective action should also be investigated. Stocking interventions in communally managed water bodies have the potential to inflame latent conflicts in villages which already have weak social cohesion. A good indicator is the existence of strong Death Donation Societies which tend to be the village institutions that are most representative of poorer households. Checking membership and attendance records is a useful check of the social capital within the PC. While such characteristics are likely to be highly site specific, in some instances low-caste communities surrounded by higher-caste settlements proved extremely cohesive by virtue of their marginalisation.

The likelihood of successful collective action is also likely to be enhanced when the intervention communities live close by, ideally within view, of the tank(s) which are to be stocked. This assists in observation of rules and prevents free-riding.

7.7.4 Working with communities to improve productivity of seasonal tanks

Developing a shared understanding of the approach to and the benefits possible from managing seasonal tanks more productively, requires facilitation of adaptive learning over a full season by outside institutions, through viable local institutions. The following were key aspects of iterative community meetings held by the DDS to monitor enhanced benefits in piloted tank projects.

- Community monitoring through transparent record keeping of yields and expenditure of fish purchase saved. A range of direct observation and stratified survey techniques will be required to capture the cumulative benefits of intermittent ‘staggered’ harvesting.
- Promotion of hook and line intermittent harvest using non-live lures
- Community meetings in which overall benefits were discussed.
- Simultaneous promotion in neighbouring communities and watersheds so that reduced inter-community access is compensated by higher outputs from local tanks, together with savings in travel time.

However, if adaptive learning is to be incorporated in a sustained process of beneficial change, the transaction costs of monitoring must also be met. Ideally in future these will be raised from the fishery by some component of the action plan. One option is to promote stocking as a component activity of integrated small water-user-groups, i.e. rather than placing it under the auspices of specialist fishing societies. These groups would combine fish enhancements with other productive water-uses, particularly micro-industries such as brick-making, which require no access to cultivatable lands. This could help overcome mobilisation problems where the outputs of individual activities are too low or seasonal to attract sustained participation.

7.7.5 Implications for tank rehabilitation

The potential negative effects of tank rehabilitation prompt an assessment of rehabilitation approaches; following are suggestions for maintaining or improving fish production in tanks.

- *Refuge areas:* Excavation of small refuge areas (15-20m^2) close to the bund can improve dry season carryover of fish stocks, whilst simultaneously maintaining deeper weed free areas for bathing. These could be designed in conjunction with the installation of concrete bathing access steps to improve access and reduce bund erosion.

- *Increasing tank capacity*: This can be achieved by (1) by removal of sediment to deepen the tank and / or (2) raising the height of earthen bunds or surplus weirs extending the area covered by the tank. Each approach has merits and disadvantages with respect to fish productivity. De-silting can adversely affect nutrient status and impact directly on fish production through reduction in spill frequency. Meanwhile the benefits of increased dry season storage will be contingent on the extent to which irrigation demands are intensified. Increasing bund / surplus weir height can increase fish productivity through the inundation of highly productive shallow littoral areas for longer periods but may also result in inundation of productive lands above the tanks. An assessment of watershed hydrological endowment using the method described in Chapter 2 should be used to assess the likely outcome of these different rehabilitation measures on fish production.
- *Migration-friendly surplus weir design*: There is a trend to install concrete surplus weirs on progressively smaller tanks replacing traditional earthen weirs. This represents an additional constraint to migration, which could be overcome by simple design modifications.

In conclusion, this study has demonstrated that stocking strategies based on locally available seeds, combined with tank rehabilitation sympathetic to preservation of upstream hydrological linkages, are highly complementary enhancement steps. Together they have potential to maintain the wider aquatic ecosystem on which the poorest groups depend.

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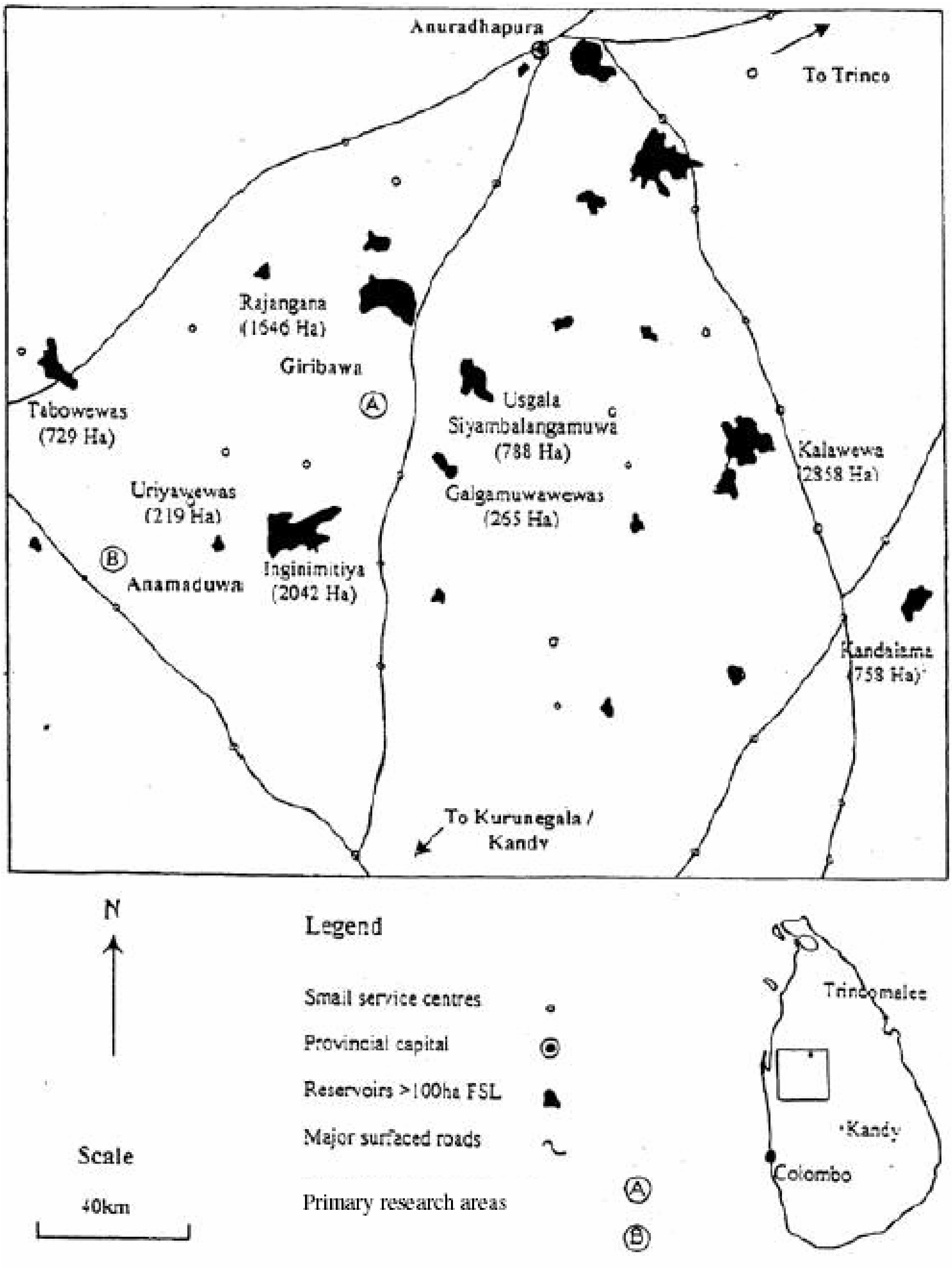
Appendices

Appendix 1 Location of minor and and major perennial reservoirs with commercial fisheries in primary research areas of Giribawa and Anamaduwa Divisional Secretariats



Appendix 2 Administrative Districts, agro-climatic zones and principle towns in Sri Lanka.

Provinces and Districts

Northern Province
Vavunia
Mannar
Mullaitivu
Jaffna
Kilinochchi

North Central Province
Anuradhapura
Polonaruwa

North Western Province
Kurunegala
Puttalam

Central Province
Kandy
Matale
Nuwara Eliya

Eastern Province
Trincomalee
Batticaloa
Amparai

Western Province
Colombo
Gampaha
Kalutara

Uva Province
Badulla
Moneragalla

Sabaragamuwa Province
Kegalle
Ratnapura

Southern Province
Galle
Matara
Hambantota

Appendix 3 District wise GDP and development indices in districts of the Dry-Zone, Sri Lanka (HDR 1998)

Dry-Zone district	GDP (Rs) *per capita* 1994	Human Development Index (HDI[1])	Human Poverty Index (HPI[2])	Gender Development Index (GDI[3])	Gender Empowerment Index GEI[4])
Matale	7592 (9)	0.73 (12)	21.5 (9)	0.46 (10)	0.18 (11)
Hambantota	7119 (13)	0.74 (9)	23.3 (11)	0.47 (9)	0.23 (8)
Kurunegala	8905 (7)	0.88 (2)	22.2 (10)	0.48 (7)	0.26 (7)
Puttalam	7314 (11)	0.73 (13)	19.1 (6)	0.36 (17)	0.03 (17)
Anuradhapura	10832 (5)	0.85 (4)	21.3 (8)	0.56 (1)	0.32 (2)
Polonnaruwa	9047 (6)	0.87 (3)	27.7 (15)	0.56 (2)	0.3 (4)
Moneragala	6659 (17)	0.69 (16)	28.7 (16)	0.41 (14)	0.12 (15)
Sri Lanka Total/Average	**8411**	**0.75**	**17.76**	**0.465**	**0.21**

[1]HDI variables = Life expectancy, adult literacy, primary to tertiary education enrolment, real GDP *per capita*.
[2]HPI variables = Mortality before age 40, primary & secondary education enrolment, access to safe drinking water, safe sanitation, child birth outside formal medical institutions, Immunisation of population and pregnant women against infectious diseases, access to electricity.
[3]GDI = Calculated as for HDI but differentiated by gender.
[4]GEI: variables = parliamentary, managerial, professional representation & proportion of national income earned by females.

Appendix 4 Poverty indicators for districts within the lowland Dry-Zone.

	Agro Ecological Zone[1]	Land Area (km^2)	Population (Per Km^2) 1995	GDP $ *Per Capita* 1994	% Adult Illiteracy 1994	Schooling % Non Enrolment Grade 1-9	% Temp. Housing[5]	% w/o Access to Electricity 1994	Unprotected water supply 1994[2]	% w/o Safe Sanitation 1994[3]	% Low Birth Weight 1996[4]	% Birth not in Institutions 1994	Infant Mortality (/1,000 Births) 1989	Within War Zone?
Central Province														
Matale	IZ & DL1	1,988	224	121	13.5	15.3	42.9	72.8	27.3	30	22.1	17.3	10.2	No
Southern Province														
Hambantota	DL 5 & DL1	2,593	206	113	13.1	12.6	42.1	74.4	28.3	26.4	14.6	15.9	5.2	No
Nothern Province														
Jaffna and Killinochi	DL3 & DL4	2,072	494						10.8	46.2	14.8	17.7	15	Yes
Mannar	DL3, DL4 & DL1	2,002	67						7.8	77.4	17.2	36.5	15	Yes
Vavunia	DL1	2,645	45						17.5	77.6	9.8	36.4	7.5	Yes
Mullaitivu	DL1 & DL3	1,966	50						33.8	83.9	15.9	44.7	10	Yes
Eastern Province														
Batticaloa	DL2	2,465	174						18.3	82.4	16.6	48.6	10	Yes
Ampara	DL2 & DL1	4,539	109						26.1	71.1	10.6	34.9	8.1	Yes
Trincomalee	DL1 & DL2	2,618	125						27.2	64.9	12.8	48.7	7.1	Yes
North-Western Province														
Kurunegala	WZ,IZ & DL1	4,773	312	141	8.8	12.8	43.5	76.6	27.5	46.1	19.4	10.9	16	No
Puttulam	WZ,IZ & DL1	2,977	209	116	7.3	6.3	42.8	60.1	28.3	62.2	17.1	14.7	17	No
North Central Prov.														
Anuradhapura	DL1	7,129	103	172	9.6	6.4	46.3	67.4	36.7	59.6	21.6	15.3	19.4	No
Polonaruwa	DL1 & DL2	3,404	96	144	9.5	20.3	44.8	77.1	63.7	26.1	18.6	24.7	10.4	No
Uva Province														
Monoragale	IZ, DL1 & DL2	5,587	66	106	15.9	10.2	42.5	83.2	47.3	39	18.8	31.1	4.1	No
Country Mean/Total		**64,652**	**279**	**141**	**8.9**	**8.7**	**33.5**		**27.9**	**33.5**	**18.2**	**78.3**	**18.4**	

[1] DL = Dry Land Zone, IZ = Intermediate Zone, WZ = Wet-Zone (see Chapter 1). [2] Households with access only to unprotected well or river supply. [3] Households without sealed, pit or bucket latrine.
[4] Births below 2500g. [6].Housing of mud and cadjan construction (Demographic housing survey, 1994, release 2). **Sources:** Annual Health Bulletin 1994/96, NHDR 1998, Medical Stats Unit 1996).

Appendix 5 Poverty and water resource indicators for Divisional Secretariats of North West, North Central and Northern Provinces.

Divisional Secretariat No	District & Divisional Secretariat (DS) Name	Agro-Ecological Zone	Km from Coast	Infant nutrition (under 5's) Stunting %	Wasting %	Underweight %	Infant mortality /1,000 births	% Temp House	Samurdhi Total %	Tanks <500 ha	Tanks <500 ha	Mahaweli Development area?[1]
	Puttulam			32.1	16.2	4.1	20.3					
1	Anamaduwa	DL1	20	11.1	21	9.8	1.8		56.8			No
6	Karuwalagaswewa	DL1/DL3	12				3.4					No
8	Mahakumbukkadawala	DL1/DL3	8	17.1	17.5	42.1	0					No
12	Nawagattegama	DL1	27	32.4	21.3	56.5	0					No
13	Pallama	DL3	5	26.5	22.3	49.9						No
15	Wanathavilluwa	DL3	5	22.9	1.6	66.9	7.6					No
	Kurunegala			26.7	17.5	8.4	19.6					
3	Galgamuwa	DL1/IL3	60				5.6					No
5	Giribawa	DL1	44				6.8		84			No
9	Kotawehera	DL1/IL3	33				6					No
13	Mahawa	DL1	47									No
22	Polpitigama	DL1/IL3	70	21.6	29.3	39.3	8.4					No
	Nikaweratiya	DL1	31				3.3					No
25	Mahagalkadawewa	DL1	38			44.5	16					
	Maho						8.7					No
	Anuradhapura			29.6	22.3	6.8	21.3					
2	Galnewa	DL1	68	18.2	18.2	42.9	19.5	32	61	55		Yes (H)
4	Ipalogama	DL1	82				3.2		61	50		Yes (H)
7	Kakirawa	DL1	84				28.2		42	101		Yes (H)
11	Nochiyagama	DL1	32				22.3	16	61	124		Partly (H)

Divisional Secretariat No	District & Divisional Secretariat (DS) Name	Agro-Ecological Zone	Km from Coast	Infant nutrition (under 5's)				% Temp House	Samurdhi Total %	Tanks <500 ha	Tanks <500 ha	Mahaweli Development area?[1]
				Stunting %	Wasting %	Underweight %	Infant mortality /1,000 births					
15	Palagala	DL1	74				14.3		74	92		Partly (H)
16	Palugaswewa	DL1	102				0		63	11		No
17	Rajanganeya	DL1	41				12.2		45	NA	1	Yes (H)
19	Thalawa	DL1	63				29.3	28	54	50		Yes (H)
20	Tambuttegama	DL1	53				23.2	42	38	4	0	Yes (H)
	Galenbiduwewa	DL1							61	134	2	No
	Thirappane	DL1							78	208	2	No
	Horoupatana	DL1								220	0	No
	Matale			40.6	26.3	12	13.4		67			
2	Dambulla	DL1	97	15.8	21.6	37.9	11.3			76 (3)		Partly (H)
3	Galewela	DL1/IL3	80				6.3					No
	National average											

Data Sources:
Irrigation data: Mahawelli RPM office (1998)
Nutrition indicators: District and divisional values for stunting and wasting from 1988/89 Nutritional Status Survey (Min Health and FAO)
Infant mortality: Child and maternal mortality in Sri Lanka 1991(Registrar Generals office 1998).
Other Poverty indicators: District Secretariat Anuradhapura (1998) & Divisional secretariat of relevant districts visited.
Notes:[1] Bracketed letter refers to Subsystem of Mahaweli Development programme.

Appendix 6 The project logical framework (DFID R7064: Small-scale Farmer Managed Aquaculture in Engineered Water Systems)

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Goal			
Sustainable yields from small-scale semi-intensive and extensive aquaculture systems increased through improved management.	By 2005, in target regions of four core/niche countries where demand exists: -No. of small-scale fish farmers increased by 20% - Yield of fish from on irrigation system where demand exists increased by 50% - Fish production from multiple-use ponds on small-scale mixed farms in one targeted semi-arid area increased by 20%	-Reports of target institutions - National production characteristics - Evaluation of aquaculture programme - Research programme reports - Monitoring against baseline data	- Climatic conditions remain favourable - Enabling environment (policies, institutions, markets, incentives) for the widespread adoption of new technologies and strategies exists
Purpose			
Social and bio-economic constraints to introduction of aquaculture into farmer managed irrigation systems identified and effective approaches to aquaculture developed and promoted.	By 1999, key locations/ constraints identified re: productive resources and social factors; criteria defined for aquaculture in mixed farm/ multi-use systems. By 2000, development strategies identified and promoted in selective locations/production systems.	Reports, peer review publications, extension materials and guide books, workshop proceedings, use in target locations/ communities	- Target institutions support strategic planning initiative.
Outputs			
1. The potential of aquaculture in small-scale farmer managed water resources assessed. 2. Identification and testing of research methods/ tools. 3. Approaches to key engineering and management options investigated and promoted.	1.1 By 1999, comprehensive peer-reviewed farmer-managed water resource assessment produced for Asia. 1.2 By 2000, reviews of current knowledge completed, peer reviewed and disseminated to all identified stakeholders. 2.1 By 2000, 80% of stakeholders agree to researchable constraints and disseminated to all identified stakeholders. 2.2 By 2000, a well attended regional dissemination workshop attended. 3.1 By 2000, preliminary research in case study sites leads to production of farmer-centred research agenda in conjunction with National Government Organisations/ NGO's and farmers. 3.2 By 2001, sustained improvement of resource use through integration with fish production being researched with farmers and support agencies.	Peer review publication. Edited workshop output. Research action plan Extension outputs Project memorandum for phase II farmer centred research Farmer response Research reports	Planned research to alleviate constraints conducted and strategies effective. Funds forth coming.

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumptions
Activities	Inputs		
1.1 Conduct an in-depth study and categorisation of farmer-managed engineered water resources in Asia focusing on countries and regions facing critical water stress. 1.2 Information collection. A broad sweep documenting aquaculture activities in small-scale water resources by region, type, species, socio-economic group of operators, sources of funding, nature and level of support, production, markets, etc. This would be from secondary sources, key informants and survey co-ordinated by the IOA/CLUWWR. 1.3 Produce a review and other promotional outputs. 2.1 Characterise with farmers and NARS of the researchable social, technical and economic issues relating to development of fish production in farmer-managed water resources from case study areas in Southern India and Sri Lanka. 2.2.Develop in conjunction with farmers and NARS, a farmer ranked research agenda for the development of fish production in these systems. 2.3 Hold regional workshop in use of small-scale farmer managed water resources for production of fish and other aquatic products. 3.1 Investigate options for enhanced natural fish production, cultured fish, non-fish aquatic production. 3.2 Define/ compare draw down/ water use of the land and water based production systems. 3.3 Investigate health and welfare implications. 3.4 Develop an index of water resource development potential. 3.5 Produce guidelines, information and other dissemination/ promotion materials.	1998-2001 UK Staff Travel & subsistence Overheads Capital Equipment Miscellaneous Totals £112,633	- Quarterly, annual and final progress reports, plus final report. - Quarterly financial statements of expenditure.	-Visas, access and co-operation forthcoming from authorities, target institutions, and end user groups. -Social, economic and natural environment is conducive to the development of sustainable integrated aquaculture strategies.

Appendix 7 Flow chart showing resolution from district level to selection of STCs (see Chapter 1 for details of methodology used in selection process and Appendix 8 for location of STCs screened at level 4)

Level 1: Province & District

Nothern Province	**North Central Province**	**North-Western Province**	**Eastern Province**	**Central Province**	**Southern Province**
Jaffna & Killinochi Mannar Vavunia	Anuradhapura Polonaruwa Uva Province Monoragale	Kurunegala Puttulam	Batticaloa Ampara Trincomalee Mullaitivu	Matale	Hambantota

Level:2 District

Anurahdapura	Puttalam	Kurunegala	Matale

Level 3. D.S.

Tirappane Kahatagasdigiliya Nochchiyagama	Anamaduwa	Galgamuwa Giribawa Polpitigama	Dambulla

Level 4. Cascade

Tirappane DS 6. Mahakanamulla 7. Pahala Ambathale **Kahatagasdigiliya DS** 12. Moraganawella **Nochchiyagama DS** 13. Dambawelegama	1. Pahala Diulwewa 14. Andarawewa	**Galgamuwa DS** 2. Danduwellawe 10. Nitalawa 11. Bedigama **Giribawa DS** 5. Ihala Marankadawela **Polpitigama DS** 8. Mamunugama 9. Amunokole	3. Ethabendawewa 4. Digampatana

Note: Numbers refer to map locations shown in Figure 11.

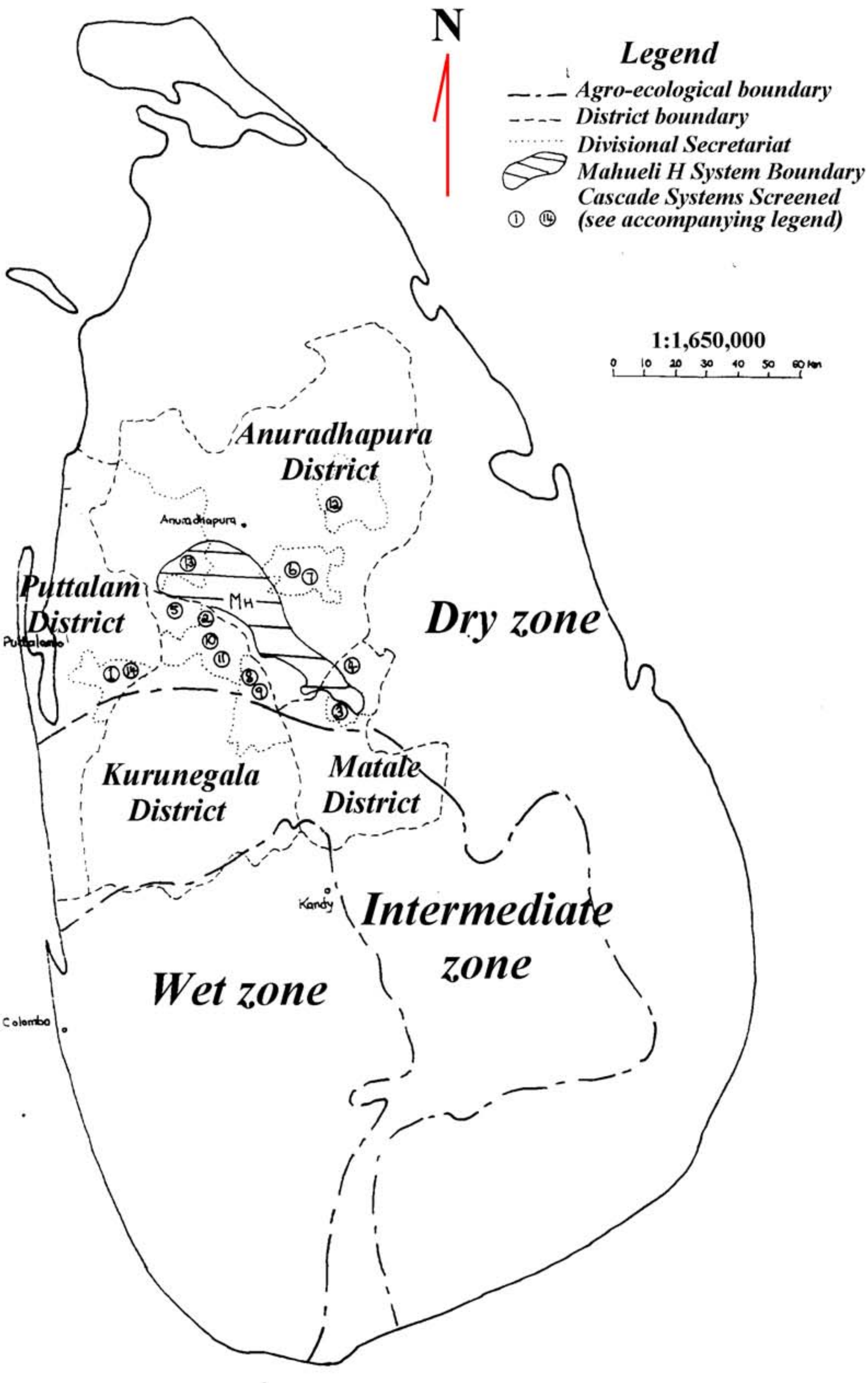
Level 5: Cascade level

Pahala Diulwewa	Danduwellawe

Notes on resolution levels

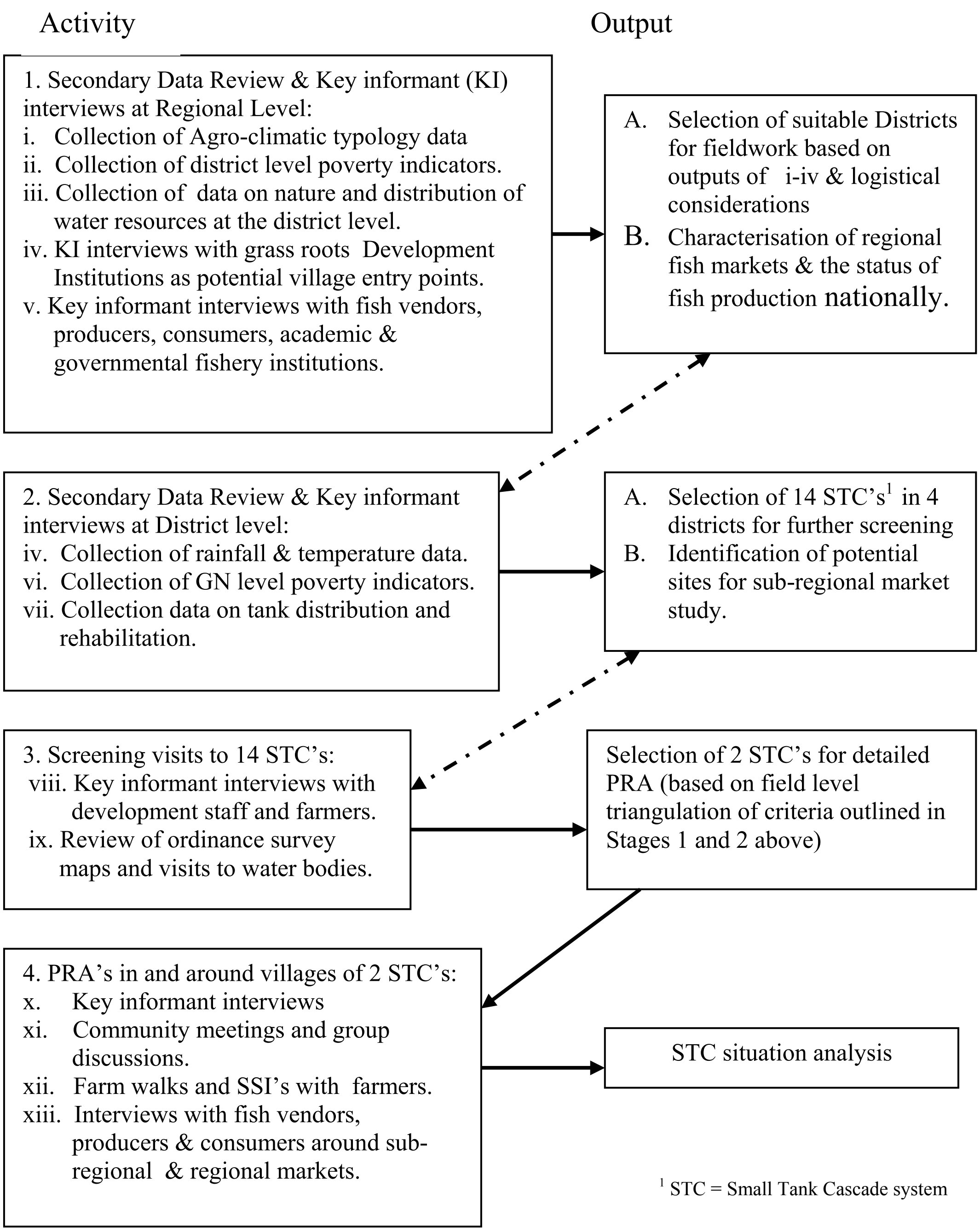
- **Level 1:** Provinces and Districts located within the Dry-Zone of Sri Lanka.
- **Level 2:** Selection of 4 districts based on suitable water resource availability, poverty and logistical criteria (including proximity to Linked KAR engineering programme in Mahaweli H system and location out-with primary conflict areas).
- **Level 3.** Selection of 8 Divisional Secretariats (DS) based on poverty criteria and water resources suitable for aquaculture.
- **Level 4:** Selection of 14 Cascade systems for field visits based on (*Grama Niladhari* (GN) level) poverty data and suitable water availability
- **Level 5:** Selection of 2 cascades for in-depth study based on rapid screening visits made to cascade systems identified in level 4 and presence of suitable institutional entry points.

Appendix 8 Map showing location of Small Tank Cascade systems (STCs) subjected to a rapid screening process (see Appendix 7 for key to locations)



Appendix 9 The preliminary situation anlaysis framework 1998/99

Figure 9: The research framework, including methodology for identification of field research areas (Solid arrows = sequential activities, Broken arrows =Iterative activities).



Appendix 10 Statistical analysis of ranking and scoring results for water-use priorities in Pahala Diulwewa and Danduwellawe villages.

A10.1. Friedman test for Danduwellawe water resources

```
S = 25.73  DF = 5  P = 0.000
S = 27.93  DF = 5  P = 0.000 (adjusted for ties)
                    Est     Sum of
Treatment      N   Median    Ranks
Bathing      16    7.208     81.5
Bricks       16    1.208     36.0
Domestic     16    2.042     50.5
Fish         16    2.208     48.5
Irrigation   16    6.708     71.5
Livestock    16    2.375     48.0

Grand median  =    3.625
```

A10.2 Mood median test for Pahala Diulwewa water resources

```
Chi-Square = 25.12   DF = 5   P = 0.000
                                        Individual 95.0% CIs
Criteria    N<= N> Median Q3-Q1 -----+---------+---------+---------+-
Bathing     13  15  5.50  4.75                 (------+--)
Bricks      25   3  1.00  2.00  +-------)
Domestic    22   6  3.00  2.50       (----+
Fish        19   9  4.00  3.00            (----+--)
Irrigation  10  18  6.00  6.00       (------------------+---------)
Livestock   14  14  4.50  4.00         (----------+-)
                                -----+---------+---------+---------+-
                                    2.0       4.0       6.0       8.0
Overall median = 4.00
```

A10.3 Friedman test for Pahala Diulwewa water resources

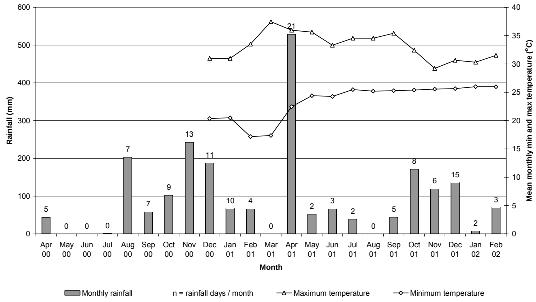
```
S = 27.75  DF = 5  P = 0.000
S = 29.34  DF = 5  P = 0.000 (adjusted for ties)
                    Est    Sum of
Criteria       N   Median    Ranks
Bathing      28    4.792    121.0
Bricks       28    1.625     62.0
Domestic     28    2.708     82.0
Fish         28    3.375     96.5
Irrigation   28    5.875    122.5
Livestock    28    4.375    104.0

Grand median  =    3.792
```

A10.4 Mood median test for Danduwellawe water resources

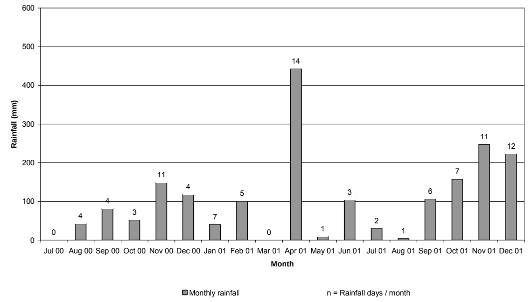
```
Chi-Square = 25.90   DF = 5   P = 0.000
                                        Individual 95.0% CIs
Criteria    N<= N> Median Q3-Q1 +---------+---------+---------+------
Bathing     2    14  7.0   9.3                 (---+---------------)
Bricks      13    3  1.0   2.7  (-+---)
Domestic    11    5  2.5   7.0  (-----+-----)
Fish        13    3  2.5   1.0       (+-)
Irrigation  5    11  8.0   8.0    (-----------------+-)
Livestock   10   6   2.5   4.0  (-----+---)
                                +---------+---------+---------+------
                               0.0       4.0       8.0      12.0
Overall median = 3.0
```

Appendix 11 Rainfall data collected at intervention sites Apr 00 to Feb 02

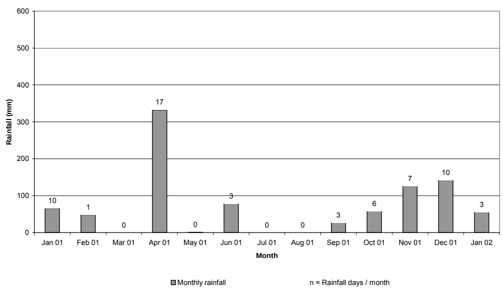
A11.1 Monthly rainfall, rainfall days, min and max temp., recorded at Galgamuwa and by farmers at five intervention sites in the Giribawa area Apr 00 to Feb 02



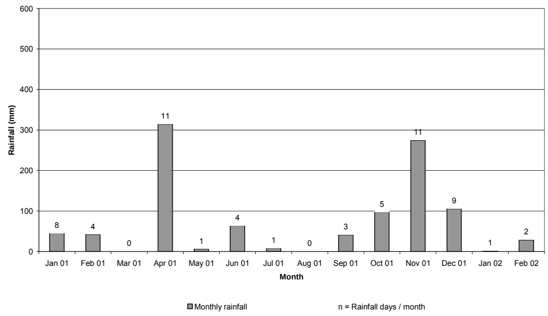
A. Galgamuwa



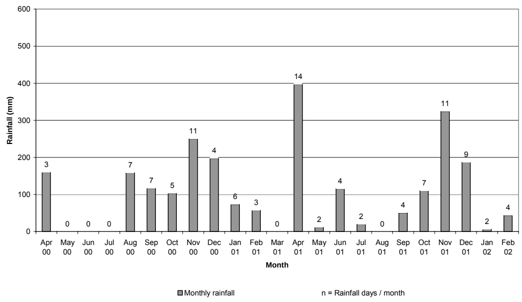
B. Danduwellawe



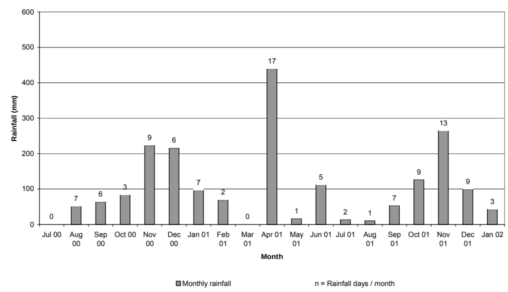
C. Maduragama



D. Galenbindunewewa



E. Gurulupitigama



F. Ihala Maradankadawala

A11.2 Summary rainfall characteristics Jan – Dec 2001

Location	Annual RF (mm)	April RF (mm)	Annual rain days
Galgamuwa	1295	529	76
Danduwellawe	1465	443	69
Maduragama	878	332	57
Ihala Maradankadawala	1302	439	73
Gurulupitigama	1346	397	62
Galenbindunewewa	1000	315	57

Appendix 12 Surplus weir design moving from upper to lower-watershed locations

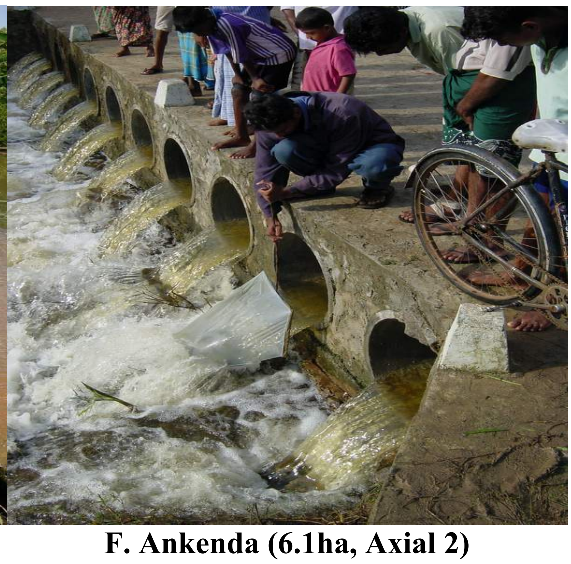
A. Karamba (1.89ha, Axial 1)

B. Ulpath (2.02ha, Radial)

C. Serugas (3.25ha, Radial)

D. Mahagalketiyawa (3.5ha, Radial)

E. Luna (3.79ha, Radial)



F. Ankenda (6.1ha, Axial 2)

G. Galenbindenawewa (8.42ha, Axial 1) **H. Lokahettiyagama (13.56ha, Axial 1)**

I. Ihala Maradankadawala (18.1ha, Axial 2) **Gurulupitigama (20.8ha, Axial 3)**

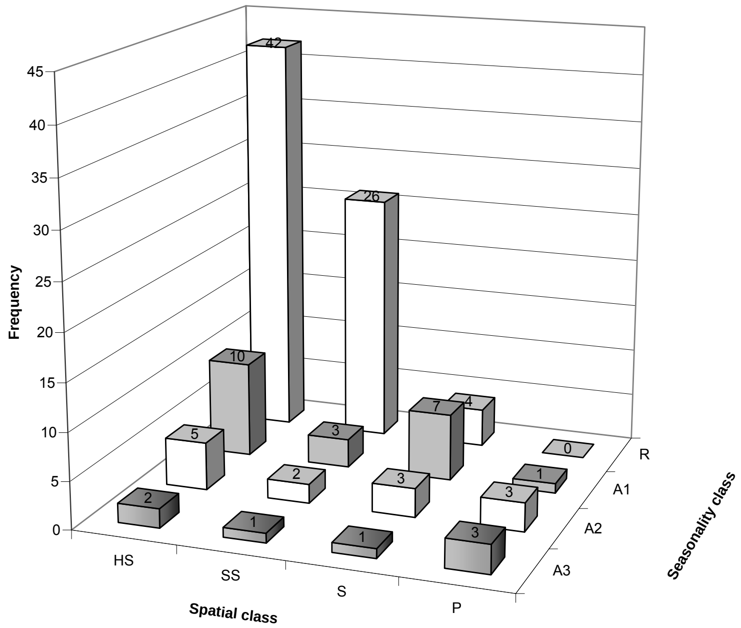
K. Mahagalkadawala (63ha, Axial 4) **L. Pahala Giribawa (28ha, Axial 4)** **J. Pahala Maradankadawala (98.8ha, Axial 4)**

Appendix 13 Summary statistics for tank aquatic production typologies

A13.1 Typological frequency cross-tabulation of spatial and seasonality classes for 119 tanks in Anamaduwa and Giribawa Research areas

Tank Class[1]	HS	SS	PS	P	Total / mean
Frequency					
R	42	26	4		72
A1	10	3	7	1	21
A2	5	2	3	3	13
A3	2	1	1	3	7
A4				6	6
Total	59	32	15	13	119
Mean size (ha)					
R	1.55	4.03	6.50		2.72
A1	2.49	7.38	10.11	8.42	6.01
A2	2.99	7.06	11.47	16.08	8.60
A3	2.84	12.50	17.41	12.82	10.58
A4				35.61	35.61
Weighted Mean	1.88	4.80	9.90	23.75	
Standard deviation (ha)					
R	0.67	2.97	3.75		1.67
A1	1.33	4.25	14.40		6.04
A2	4.00	4.33	7.66	10.32	6.36
A3	1.72			5.09	2.67
A4				37.19	37.19
Weighted Mean	1.10	3.09	9.25	20.72	

[1] HS = highly seasonal, SS = semi-seasonal, PS = periodic seasonal, P = Perennial
Results exclude Uriawewa (84ha) a system tank at the base of Pahala Diulwewa cascade, Anamaduwa



A13.2 Graph of typological frequency cross-tabulation for119 tanks in Anamaduwa and Giribawa Research areas (frequencies indicated)

Appendix 14 Inventory of tanks in nine watersheds of the Giribawa research areas

Map No	Cascade Name	PC Name	Tank name	Spatial Class	Seasonality class	MWS (ha)	Catch area (>=ha)	CMD (ha)
1	MAD	MAD	Hangogamawewa	R	SS	3.50	20.24	8.10
2	MAD	MAD	Private 1	R	HS	2.02	12.15	0.81
3	MAD	MAD	Private 2	R	HS	2.02	12.55	0.81
4	MAD	MAD	Lunuwewa	R	HS	3.79	12.15	3.24
5	MAD	MAD	Karambewewa	A1	HS	1.89	4.05	3.64
6	MAD	MAD	Mahagalawewa	R	SS	4.00		
7	LHG	LHG	Ihala Lokahettiyagama (LHG)	R	HS	2.02	22.27	3.24
8	LHG	LHG	Lokahettiyagama	A1	SS	13.56	20.24	10.12
9	GBW	GBW	Girugoda wewa	R	SS	4.00		
10	GBW	GBW	Pahala Giribawa	A4	P	89.00		
11	POT	POT	Sundara	R	SS	4.00		
12	POT	POT	Gamankede	A1	SS	4.00		
13	POT	POT	Potanagama (POT)	A2	SS	4.00		
14	IMK	POT	Kumbukwetiya	R	HS	1.60		
15	MAD	IMK	Maduragamawewa (MAD)	R	HS	1.21	4.05	2.43
16	IMK	IMK	Ukkubandagewewa	R	HS	2.02	40.49	2.02
17	IMK	IMK	Allapathwewa	R	HS	2.43	40.49	0.61
18	IMK	IMK	Medibegamawewa	A1	S	2.02	40.49	10.12
19	IMK	IMK	Welikandawa	R	SS	2.02	28.34	14.17
20	IMK	IMK	Serugaswewa	R	S	3.25		14.17
21	IMK	IMK	Herathbandage	R	HS	0.50		
22	IMK	IMK	Ihala Beliyagama	R	HS	0.61	20.24	0.81
23	IMK	IMK	Pahala Beliyagama	A1	HS	1.62	2.02	2.83
24	IMK	IMK	Ihala Maradankadawala (IMK)	A2	P	18.10	16.19	12.15
25	IMK	IMK	Mahagalketiyawa	R	S	2.02	40.49	16.19
26	IMK	IMK	Kudagalketiya	A1	HS	2.02	4.05	6.07
27	IMK	IMK	Tharunagodawewa	R	HS	1.62	20.24	0.81
28	IMK	IMK	Kandabodawewa	R	HS	1.62	20.24	1.21
29	IMK	IMK	Ihalawewaranawetiya	R	HS	2.02	16.19	0.81
30	IMK	IMK	Wewaranawetiya	A3	P	8.10	10.12	17.81
31	IMK	IMK	Karambewewa 2	R	HS	1.89	20.24	1.21
32	IMK	IMK	Kudawewa	R	HS	1.21	12.15	8.10
33	IMK	IMK	Palugahawewa	R	HS	0.81	12.15	1.01
34	IMK	PMK	Pahala Maradankadawala Kudawewa	R	SS	2.00	12.15	3.24
35	IMK	PMK	Pahala Maradankadawala (PMK)	A4	P	14.58	20.24	12.15
36	HET	HET	Maha Keenagahawewa	R	HS	1.62	14.17	2.02
37	HET	HET	Kuda Keenagahawewa	R	HS	1.62	14.17	2.02

Map No	Cascade Name	PC Name	Tank name	Spatial Class	Seasonality class	MWS (ha)	Catch area (>=ha)	CMD (ha)
38	IMK	HET	Siyambalagaswewa	A1	SS	12.15	20.24	17.81
39	IMK	HET	Kuda Siyambalagaswewa	R	HS	1.21	6.07	4.05
40	IMK	HET	Unamed 1	R	HS	0.80		
41	IMK	HET	Unamed 2	A1	HS	1.00		
42	IMK	HET	Ulpathwewa	R	SS	6.07	16.19	1.62
43	IMK	HET	Berakarayagewewa	R	HS	1.01	6.07	2.02
44	IMK	HET	Rambawewa	A1	HS	2.02	12.15	10.12
45	IMK	HET	Daralugama	A3	HS	4.05	20.24	14.17
46	HET	HET	Levupitiyawewa	R	HS	0.81	40.49	1.62
47	HET	HET	Dikwetiya	R	HS	2.43	40.49	0.81
48	HET	HET	Millagahawewa	R	HS	2.83	40.49	4.05
49	HET	HET	Ihala Wewa	A1	S	4.05	40.49	4.86
50	HET	HET	Hettiarachiagama (HET)	A2	P	10.12	20.24	25.10
51	HET	HET	Dingiyawewa	R	HS	2.43	40.49	3.24
52	HET	HET	Weerawewa	A1	HS	2.02		6.07
53	HET	HET	Diulgaswetiya	R	HS	2.02	24.29	2.83
54	HET	HET	Aluthwewa	R	HS	1.21	12.15	1.62
55	IMK	HET	Illapathagahawewa I	R	HS	0.81	10.12	1.62
56	HET	HET	Konewetiya	R	HS	1.21	20.24	4.05
57	HET	HET	Illapathagahawewa 2	R	HS	1.21	6.07	2.02
58	IMK	HET	Godawalawewa	R	SS	1.62	3.24	2.83
59	GUR	HET	Kiriwembuwawewa	A1	HS	1.62	20.24	2.43
60	IMK	WAR	Kivulwewa	R	SS	2.80		
61	IMK	WAR	Warawewa (WAR)	A4	P	22.27	12.15	17.00
62	HET	WAR	Wanduragalawewa	A3	P	12.15	40.49	32.39
63	HET	WAR	Medawewa	A4	P	8.10	16.19	12.15
64	GUR	MDW	Kethikandewewa	R	S	10.12	20.24	8.10
65	GUR	MDW	Kalubendawewa	R	SS	2.00		
66	GUR	MDW	Maha Madawalagame	R	SS	5.00		
67	GUR	MDW	Kaluwaragaswewa	R	SS	6.07	16.19	4.05
68	GUR	MDW	Madawalagama (MDW)	A2	SS	10.12	32.39	27.94
69	GUR	MDW	Kollobendapuwewa	R	SS	4.05	20.24	4.05
70	GUR	MDW	Kudawewa	R	SS	4.05	8.10	4.86
71	GUR	GUR	Uda Wembuwa	R	HS	0.81	12.15	4.45
72	GUR	GUR	Pahala Wembuwewa	A1	HS	1.62	8.10	4.05
73	GUR	GUR	Gurulupitigama (GUR)	A3	P	25.90	12.15	22.67
74	KBK	KBK	Podiwewakotuwa	R	HS	0.80		
75	KBK	KBK	Kahatagaswewa	R	SS	2.00		
76	KBK	KBK	Rambawewa	R	S	9.00		
77	KBK	KBK	Tammemmawetiyawewa	R	SS	3.00		
78	KBK	KBK	Divulgahawewa 1	R	HS	1.50		
79	KBK	KBK	Divulgahawewa 2	A1	S	8.00		

Map No	Cascade Name	PC Name	Tank name	Spatial Class	Seasonality class	MWS (ha)	Catch area (>=ha)	CMD (ha)
80	KBK	KBK	Kumbukkallawewa	A1	SS	6.00		
81	KBK	KBK	Kumbukwewa (KBK)	A2	P	17.00		
82	GBW	GBW	Kivulwewa	R	HS	1.00		
83	GBW	GBW	Siyambalagaswewa	R	SS	1.80		
84	GBW	GBW	Ihala Galenbindunuwewa	R	SS	1.80		
85	GBW	GBW	Galenbindunewewa (GBW)	A1	S	8.42		
86	GBW	GBW	Bulnewa	R	HS	0.80		
87	GBW	GBW	Ralapanawe	A3	S	12.50		

Appendix 15 Some key findings of studies on small-scale tank hydrology in Sri Lanka.

Surface and ground water recharge: The percentage of rainfall intercepted by the catchment varies depending on the season, type of vegetative cover, topography and soil type. In a study of small tanks in Anuradhapura over four seasons, Somasiri (1982) showed that approximately two thirds of annual tank storage derives from run-off and one third from direct rainfall on the water surface. Total runoff is greatest during the main (*maha*) rainy season, varying between as much as 25% and 5% of rainfall during the *maha* and *yala* seasons respectively. Somasiri (1993) reported that runoff from scrub jungle and mature *chena* averaged 2% of the maha rainfall whilst runoff from newly cleared *chena* averages 25%. Dharmasema (1991) reported that the field capacity (the amount of rainfall a soil can intercept before it becomes saturated and surface runoff commences) of Red Brown Earths is 150mm. This amount of rainfall must be absorbed before useful runoff occurs. Soils tend to progress from more porous RBE's in the upper watershed, to relatively impermeable Low Humic Gleys (LHG's) in the lower watershed, contributing to the increased seasonality observed in upper catchments. Somasiri (1982) concluded that the irrigation potential of small tanks under forested catchment could be considered as favourable when greater than 10ha of catchment area exists for each hectare of tank capacity at 1m depth. Such tanks can attain full supply level during 40-75% of maha seasons.

Water balance: Itakura (1993) carried out the first water balance study for a complete Dry-Zone cascade. Over two seasons he found that drainage return flows (surplus irrigation waters draining from the command area immediately above a specified tank) over two *maha* seasons increased from 23% in the middle of the valley to 29% for the lowest tank, reflecting greater potential for water storage in the lower catchment. Average catchment run-off varied from 30% to 12% in *maha* and 10-4.5% in *yala*. Return flows during *yala* were zero; therefore hydrological linkages between different tanks in this STC existed only during the *maha* season.

Naveratne and Gunawardene (1999) found that direct rainfall accounted for 10% of the total harvest during during *maha*, rising to 40% in *yala.* More significantly, they found that evaporation and percolation losses account for 25-35% of storage volume compared to only 0.5% allowed for in DAS design criteria. This suggests that the existing design criteria (Ponrajah 1984) significantly over-estimate the amount of water available for irrigation.

Walsundara (1999) gives an idea of the relative significance of each of these components in the following generalised water balance estimate for dry-zone village tanks in the DL1 agro-ecological region with predominantly reddish brown soils and scrub-jungle catchment cover (Chapter 1). Around 26% of the total rainfall falling on a catchment will be intercepted by the tank as surface and sub-surface flows, 25% of that inflow will be lost due to evaporation, another 30% to percolation / seepage, leaving only11% for irrigation at the sluice outlet. However as the results presented below will show, seasonal availability of water is as critical as its absolute amount.

Appendix 16 Hydrological characteristics and cultivation outcomes (2000-2001) of tanks in a range of watershed locations including seven intervention tanks

Tank name	KRB	SER	LUN	GBW	LHG	IMK	GUR[1]	PGB[1]
Spatial classification[2]	A2	R	A1	A1	A1	A2	A3	A4
Seasonality classification[3]	HS	HS	HS	S	SS	P	P	P
Intervention phase	2	1,2	2	2	2	1	2	NA
1. Depth (m)								
Full storage (D1 - FSL to max depth)	1.90	1.70	2.10	3.20	3.30	3.10	-	-
Live storage (FSL to DSL)	1.04	1.1	1.57	1.69	2.55	1.92		
Dead storage (D4 -DSL to max depth)	0.86	0.60	0.53	1.51	0.75	1.18	-	-
2. Water surface area (ha)								
At D1 (FSL)	1.89	3.25	3.79	8.42	13.56	18.10	37.22	126.13
At D2 (DSL depth + 50% LS depth)	0.80	1.30	1.61	3.15	3.22	8.70	-	-
At D3 (50% FSL depth)	0.28	0.58	1.02	1.05	2.16	5.41	-	-
At D4 (DSL)	0.21	0.24	0.31	0.88	0.35	3.48	-	-
DSL area as % of FSL area	11.4	7.5	8.3	10.4	2.5	19.2	-	-
3. Area triangulation using planimetric method and key informant estimates (ha)								
Planimetric area	NC	3.83	3.73	5.20	8.16	19.31	25.9	89.0
Planimetric as % of topographic FSL	NC	117.9	98.2	61.7	60.2	106.7	-	-
Key informant area estimate at FSL	1.6	4.9	2	7.2	4.9	10.1	18.2	-
Key informant area estimate at DSL	0.2	0.2	0.5	0.8	1.6	1.6	4.1	-
4. Storage volume (m^3)								
At D1 (FSL)	9,642	16,330	27,976	65,398	108,243	194,495	458,314	2,272,371
At D2 (50% LS depth + DSL depth)	2,970	4,294	7,377	19,933	21,260	74,018	-	-
At D3 (50% FSL Depth)	688	1,538	3,979	5,001	11,692	32,893	-	-
At D4 (DSL)	466	554	794	4,133	724	16,407	-	-
DSL vol as % of FSL vol	4.8	3.4	2.8	6.3	0.7	8.4	-	-
5. Volume : surface area ratios (m^3 : m^2)								
FSL vol : FSL surface area	0.51	0.50	0.74	0.78	0.80	1.07	-	-
DSL vol : DSL surface area	0.22	0.23	0.25	0.47	0.21	0.47	-	-
6. Tank bed gradient (cm : m)								
MD to foreshore (G1)	1.03	1.10	1.09	1.22	0.80	0.90	-	-
DSL at bund to foreshore (G2)	0.63	0.69	0.77	0.60	0.62	0.51	-	-
7. Bund length : volume ratio and surplus weir numbers								
Bund length (m)	218	392[4]	251	373	505	620	-	-
FSL vol : length*LS ht ratio (m^3/m^2)	42.5	37.9	71	103.7	84.1	163.4	-	-
No. surplus weirs / culverts	2	1	2	1	1	1	1	1
8. Command and catchment area estimates (ha)								
Command area - survey	1.80	5.07	3.95	5.86	9.37	12.94	-	-
Net catchment area - survey	21.0	-	83.0	-	-	-	-	-
Net catchment area - planimetric	42.5	12.8	40.8	-	-	140	-	-
Gross catchment area - planimetric	83.3	12.8	40.8	272.5	184.6	374.2	-	-
9. Cropping Intensity (%) and catchment, command and water-spread area ratios (ha : ha)								
Yala cultivation 2001 (ha)	0.81	2.71	3.95	5.86	6.54	-	-	-
Maha cultivation 2001 (ha)	1.80	4.42	3.95	5.86	9.37	-	-	-
Cropping intensity (CI)	1.45	1.40	2.00	2.00	1.70	-	-	-
Catchment : FSL Water-spread (CaW)	11.08	-	21.90	-	-	-	-	-
Command : FSL Water-spread (CoW)	0.95	1.56	1.04	0.70	0.69	0.71	-	-
FSL Command (m2) : Vol (CoV)	1.87	3.11	1.41	0.90	0.87	0.67	-	-

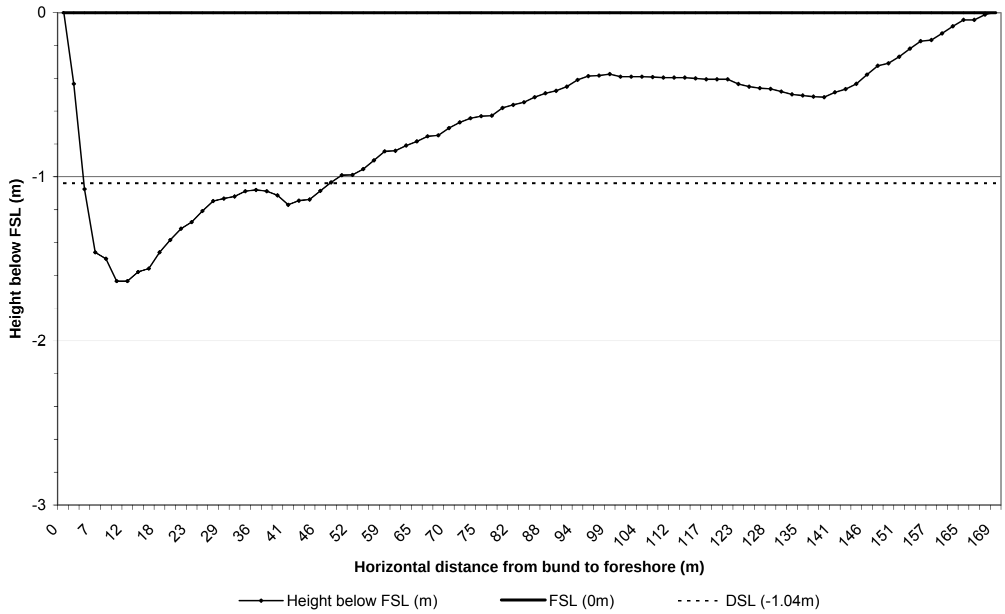
[1] Values derived from multiple-regression functions (Appendix 17) except planimetric data,
[2] 242m exclusive of freefall' bund NA = Not applicable, NC = Data not collected or available

Appendix 17 Area, volume and depth two-variable exponential regression functions for data derived from seasonal discharge curves.

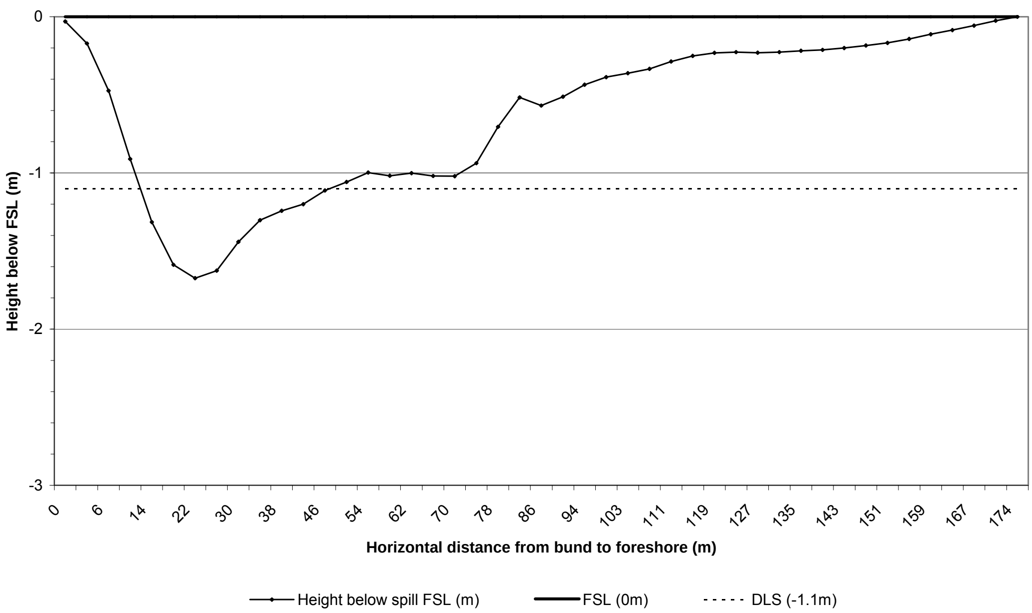
	a (factor)	b (exponent)	R^2 (Correlation co-efficient)	Function
1. Area v volume				
1.1 FSL area v FSL vol[1]	4159	1.296	0.988	$y = a\ x^b$
1.2 50% LS area v 50% LS vol[2]	3703	1.410	0.990	$y = a\ x^b$
1.3 50% FSL area v 50% FSL vol[3]	3810	1.345	0.990	$y = a\ x^b$
1.4 DSL area v DSL vol[4]	3589	1.322	0.985	$y = a\ x^b$
2. Depth v area				
2.1 LS depth v FSL area	2.13	2.315	0.790	$y = a\ x^b$
2.2 LS depth v 50% LS area	0.98	1.891	0.582	$y = a\ x^b$
2.3 LS depth v 50% FSL area	0.37	2.476	0.676	$y = a\ x^b$
2.4 LS depth v DSL area	0.26	1.486	0.225	$y = a\ x^b$
3. Depth : gradient v area				
3.1 LS depth : gradient v FSL area	0.92	2.071	0.923	$y = a\ x^b$
3.3 LS depth : gradient v 50% LS area	0.45	1.797	0.767	$y = a\ x^b$
3.4 LS depth : gradient v 50% FSL area	0.1554	2.1892	0.7711	$y = a\ x^b$
3.5 LS depth : gradient v DSL area	0.1079	1.7125	0.4364	$y = a\ x^b$
4. Depth : gradient v volume				
4.1 LS depth : gradient v FSL vol	3735.8	2.6903	0.9156	$y = a\ x^b$
4.2 LS depth : gradient v 50% LS vol	278.52	3.0676	0.8283	$y = a\ x^b$
4.3 LS depth : gradient v 50% FSL vol	1094.8	2.6417	0.8241	$y = a\ x^b$
4.4 LS depth : gradient v DSL vol	213.69	2.1288	0.3803	$y = a\ x^b$
5. Method triangulation				
5.1 Survey area v Planimetric area	1.81	0.106	0.895	$y = a\ e^{b\,x}$
6. Surface area or depth v command area				
6.1 FSL area v command area	1.4433	0.7374	0.8954	$y = a\ x^b$
6.2 FSL vol v command area	0.0146	0.5549	0.8621	$y = a\ x^b$
6.3 LS depth v command area	2.645	1.5993	0.6205	$y = a\ x^b$

[1]Area and volume obtained at FSL depth (D1) [2]Area and volume obtained at 50% LS depth + DSL depth (D2)
[3]Area and volume obtained at 50% FSL depth (D3) [4]Area and volume obtained at DSL depth (D4)

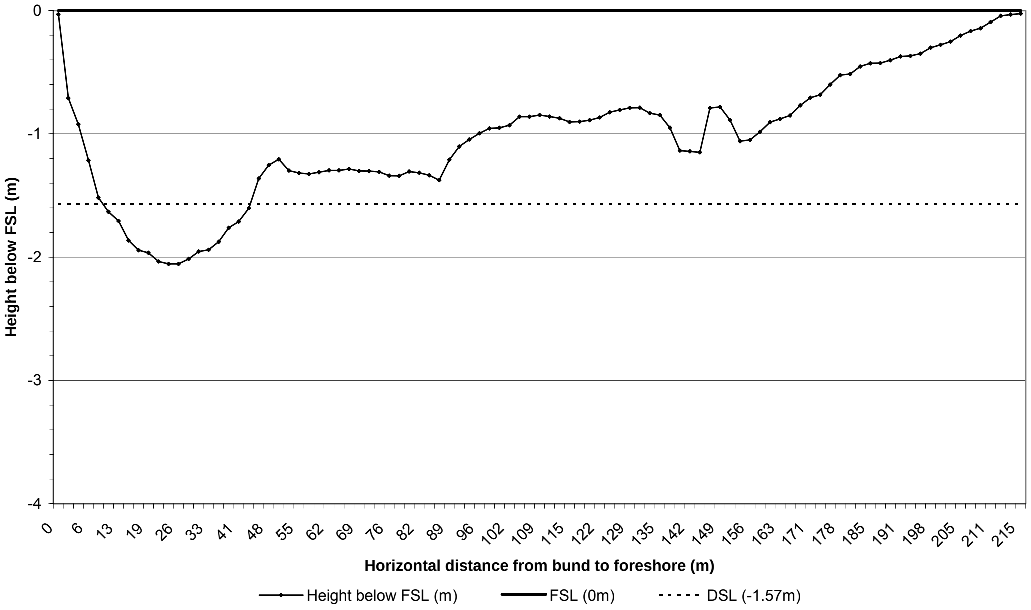
Appendix 18 Cross-sectional profiles of tank beds (all transect routes are marked on topographic maps presented in Appendix 20)



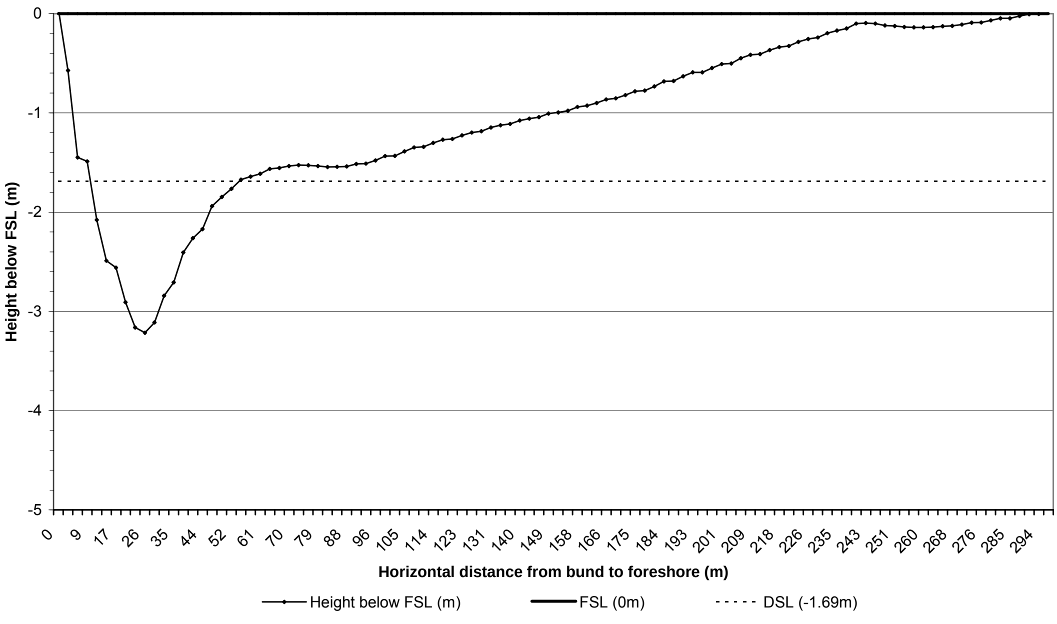
A18.1 Karambawewa



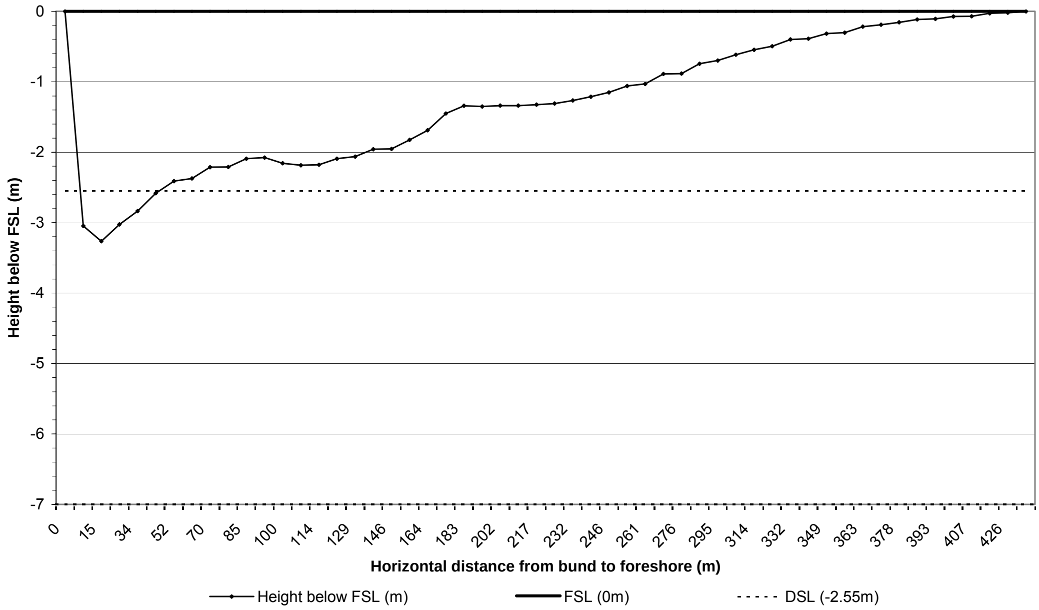
A18.2 Serugaswewa



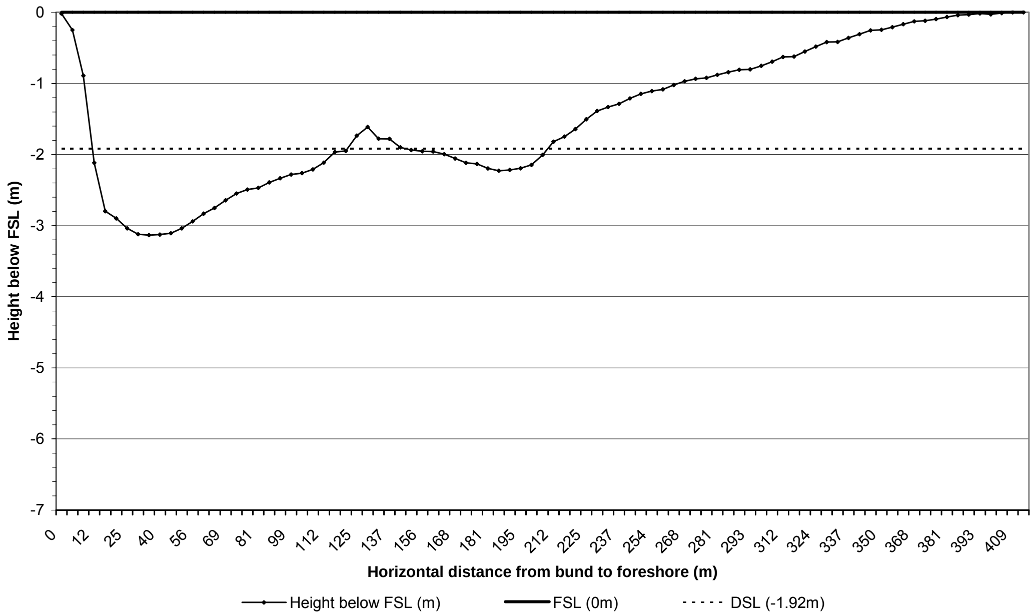
A18.3 Lunawewa



A18.4 Galenbindunewewa

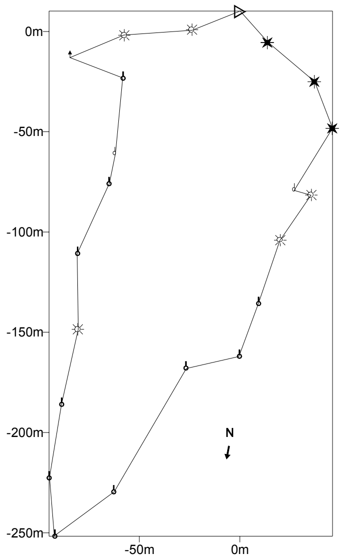


A18.5 Lokahettiyagama

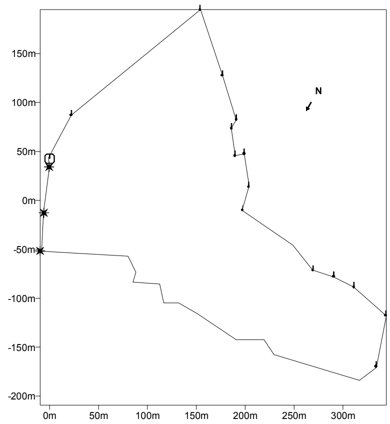


A18.6 Ihala Maradankadawala

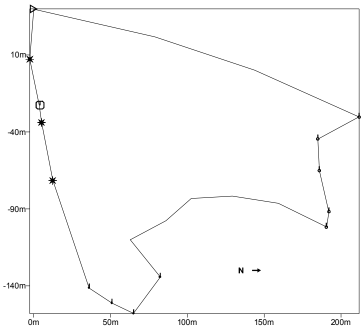
Appendix 19 Command area boundaries



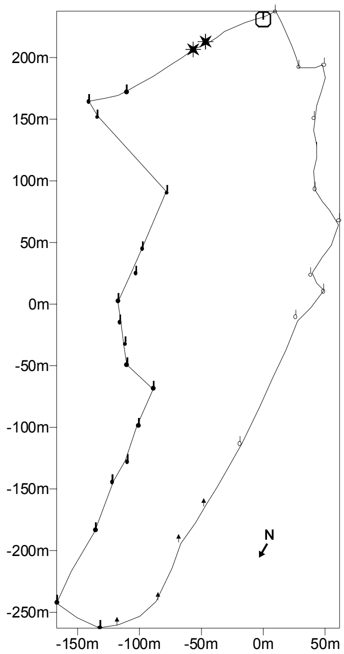
A. Karambawewa



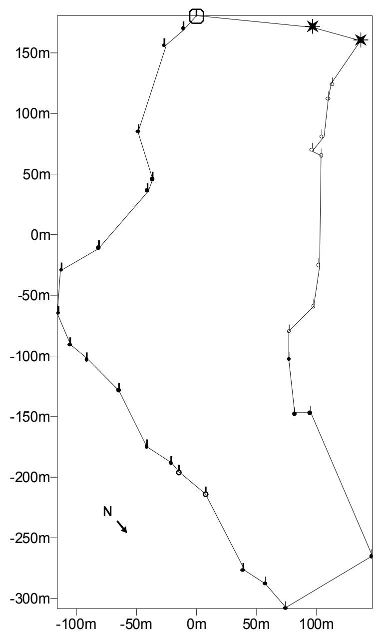
B.Serugaswewa



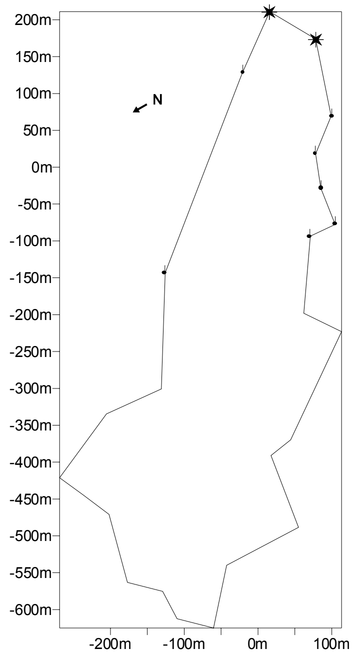
C. Lunawewa



D. Galenbindunewewa



E. Lokahettiyagama



F. IMK

Appendix 20 Contour and ‘wire-mesh’ surface plots of intervention tanks based on topographich survey (Murray 2004b)

Bund features

Sluice

Surplus weir / spillway ; earthen

Surplus weir / spillway ; concrete or stone (taken as assumed datum)

Culvert

Bathing point; earthen

Bathing point with concrete steps

IS: Instrument station (numbered)

Photographic datum

Tank bed features

Agro-well

Boundary; tank bund

Boundary; jungle

Boundary; chena cultivation

Boundary; home garden

Boundary; paddy land

Mound or ridge

Borrow pit

Path or road intersection

Tree

Tree stump

Bush

Contour features

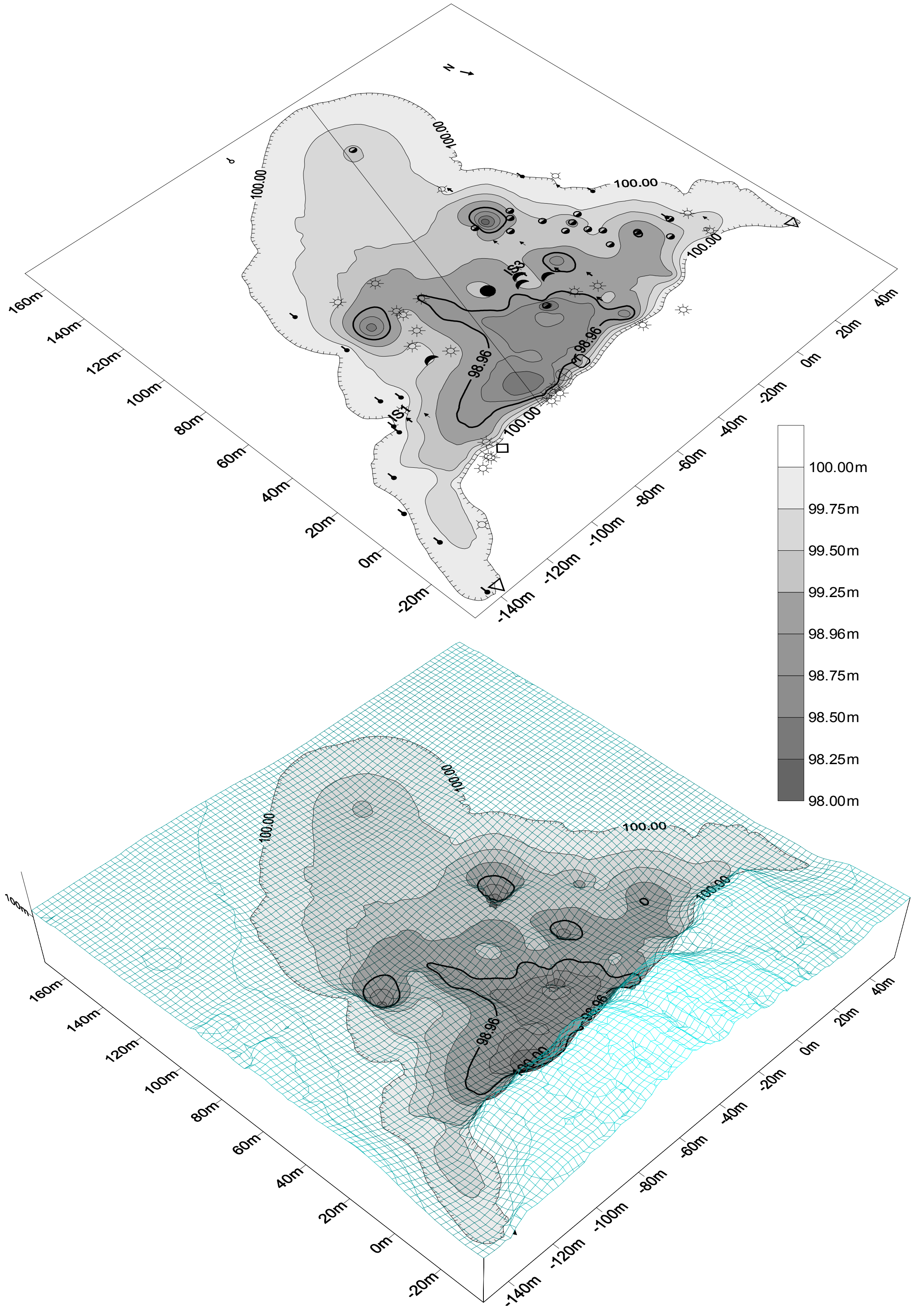
Tank bed boundary at 100m elevation w.r.t assumed datum at spillway centre

Intermediate countour at 0.2m or 0.5m intervals (indexed at 1m intervals)

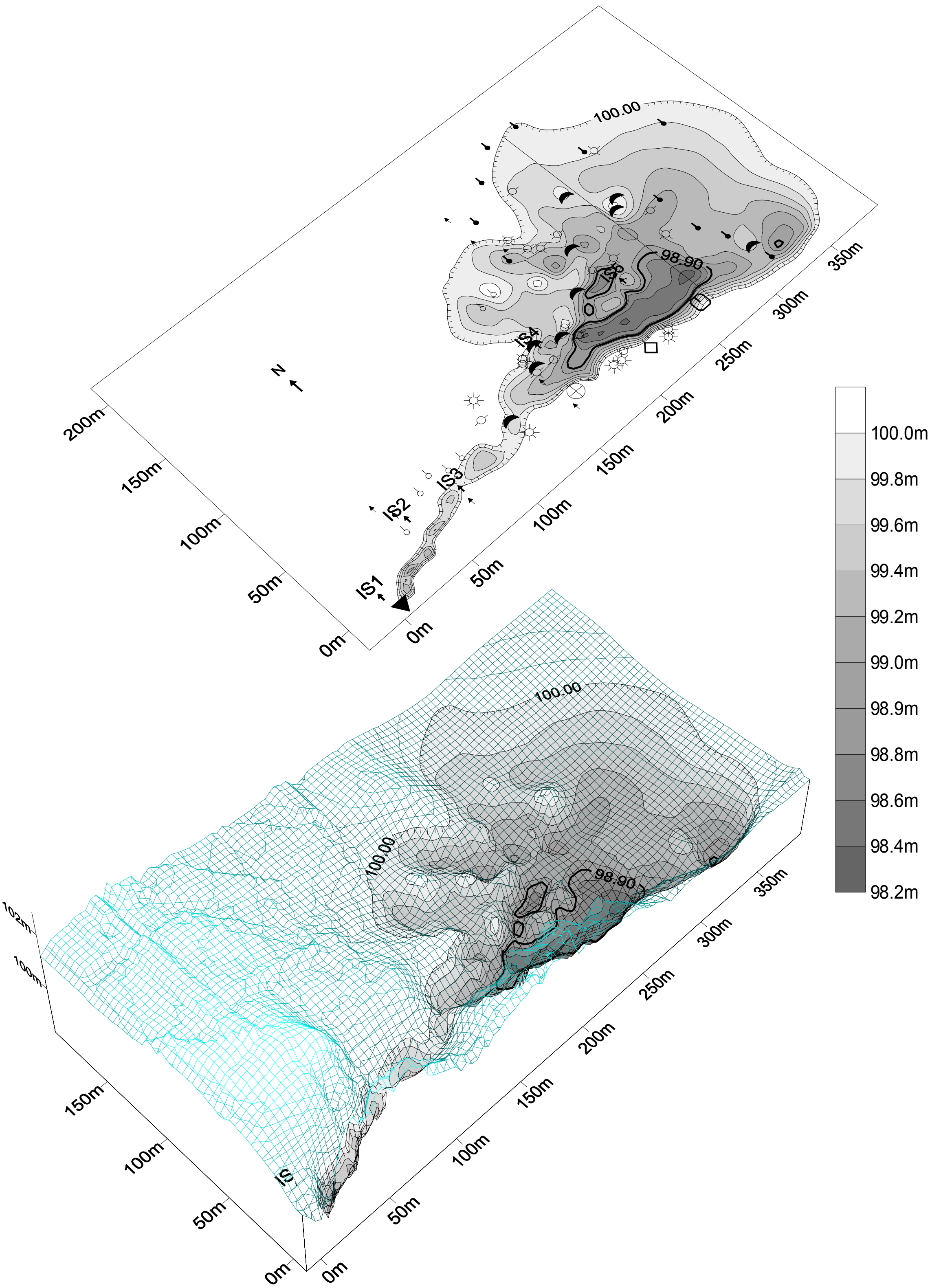
Dead storage (sill) level; indexed w.r.t. assumed datum at spillway centre

Route of transect used to generate cross-sectional tank bed profile

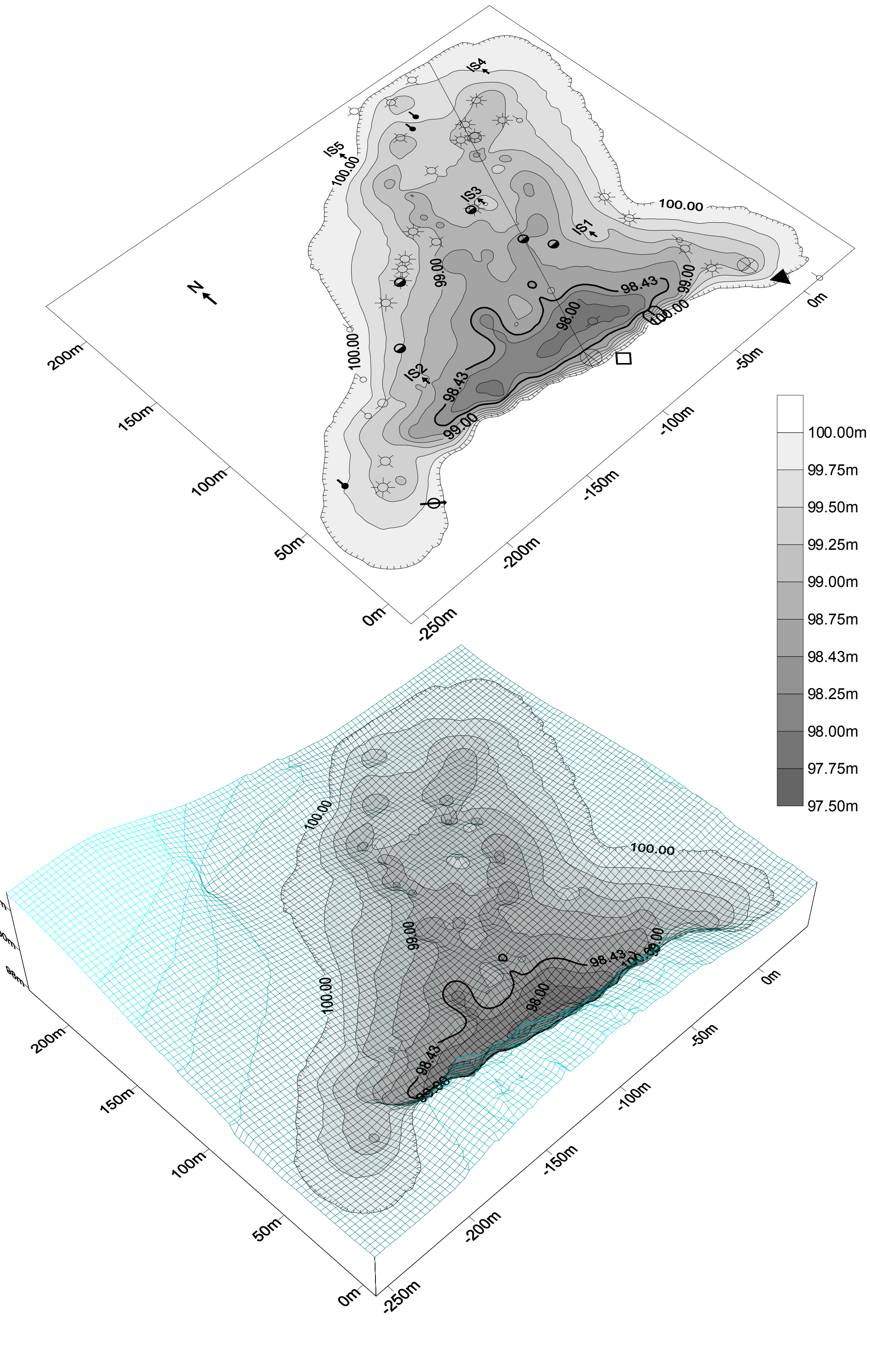
A20.1 Key to symbols used in topographic maps



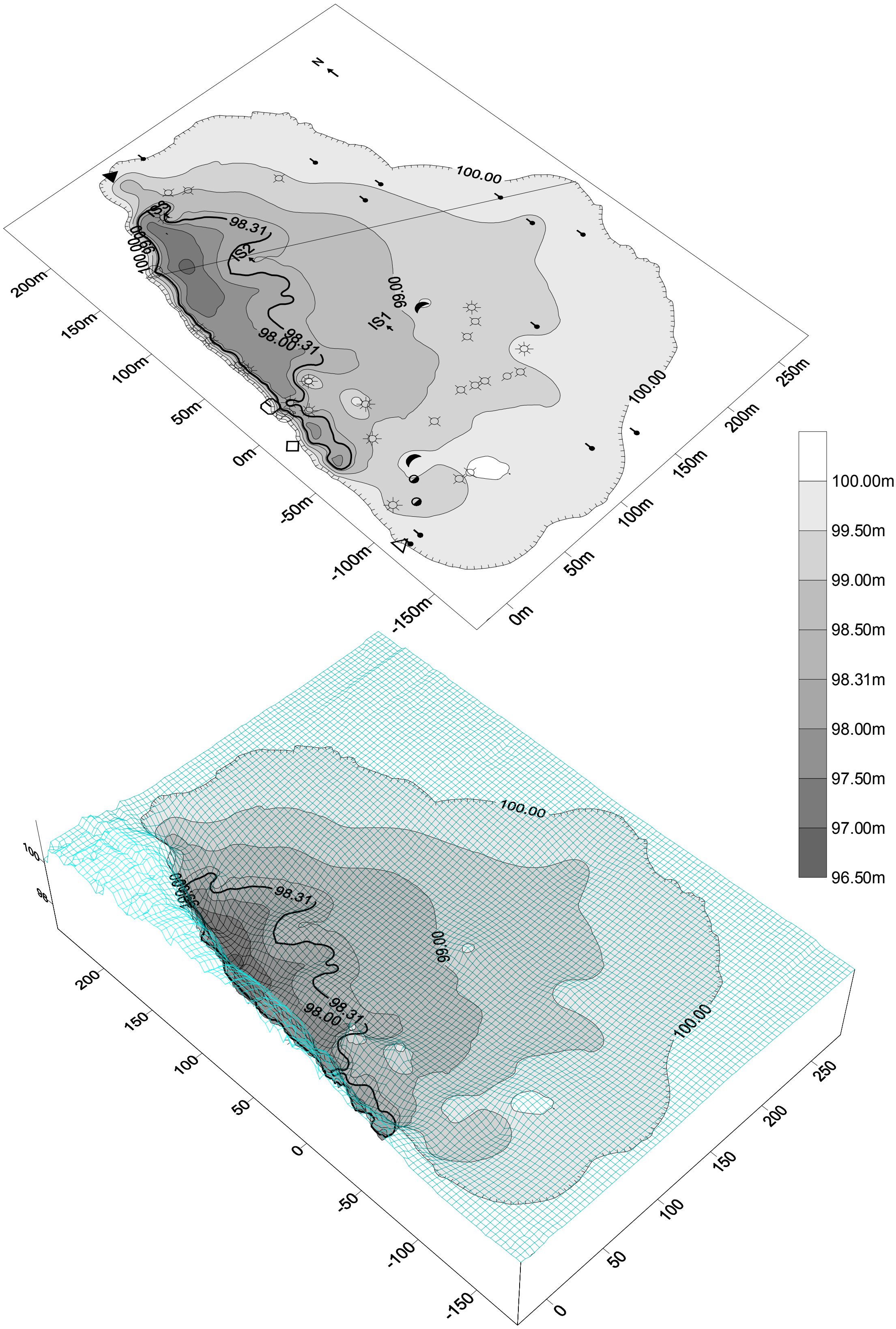
A20.2 Karambawewa



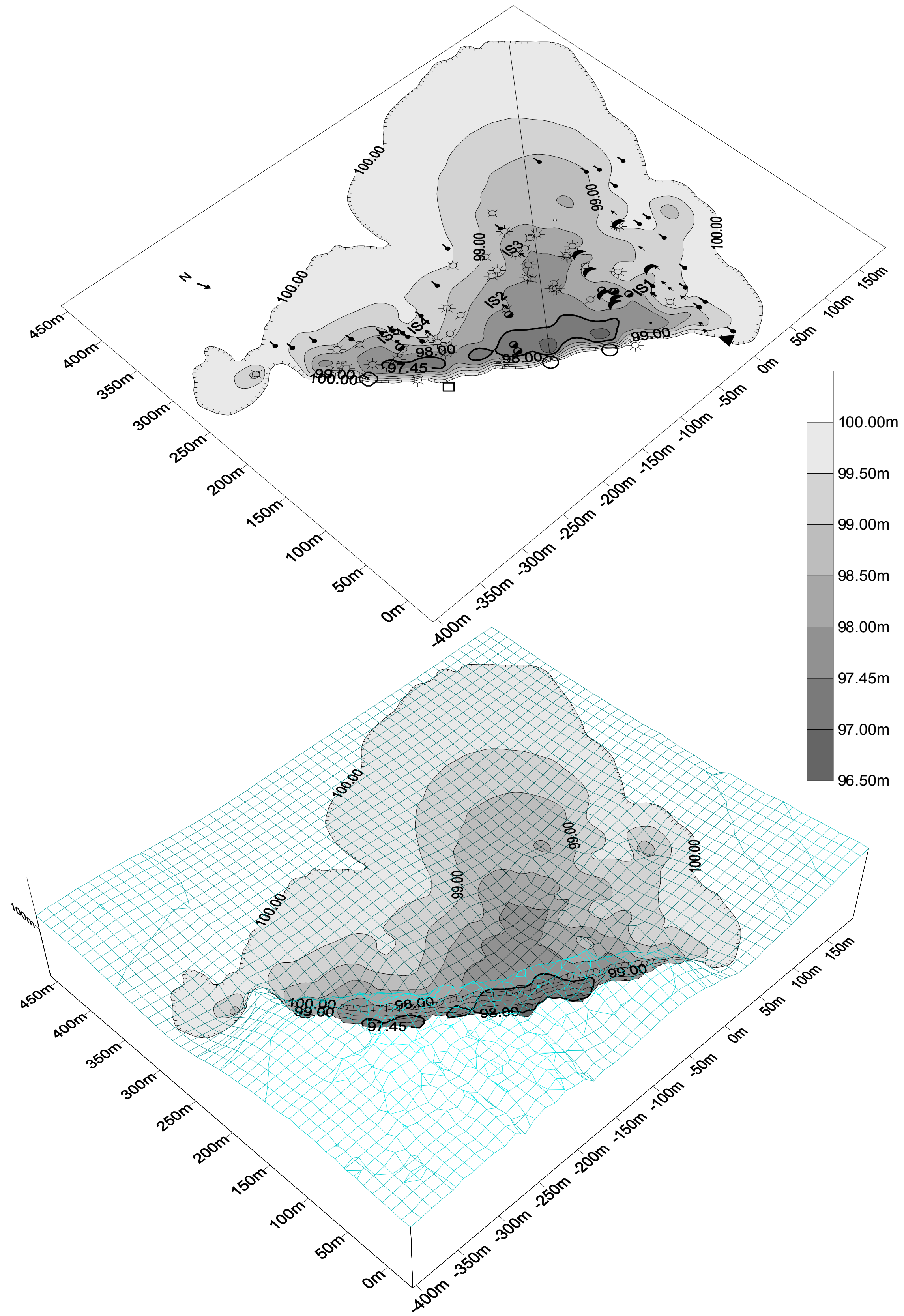
A20.3 Serugaswewa



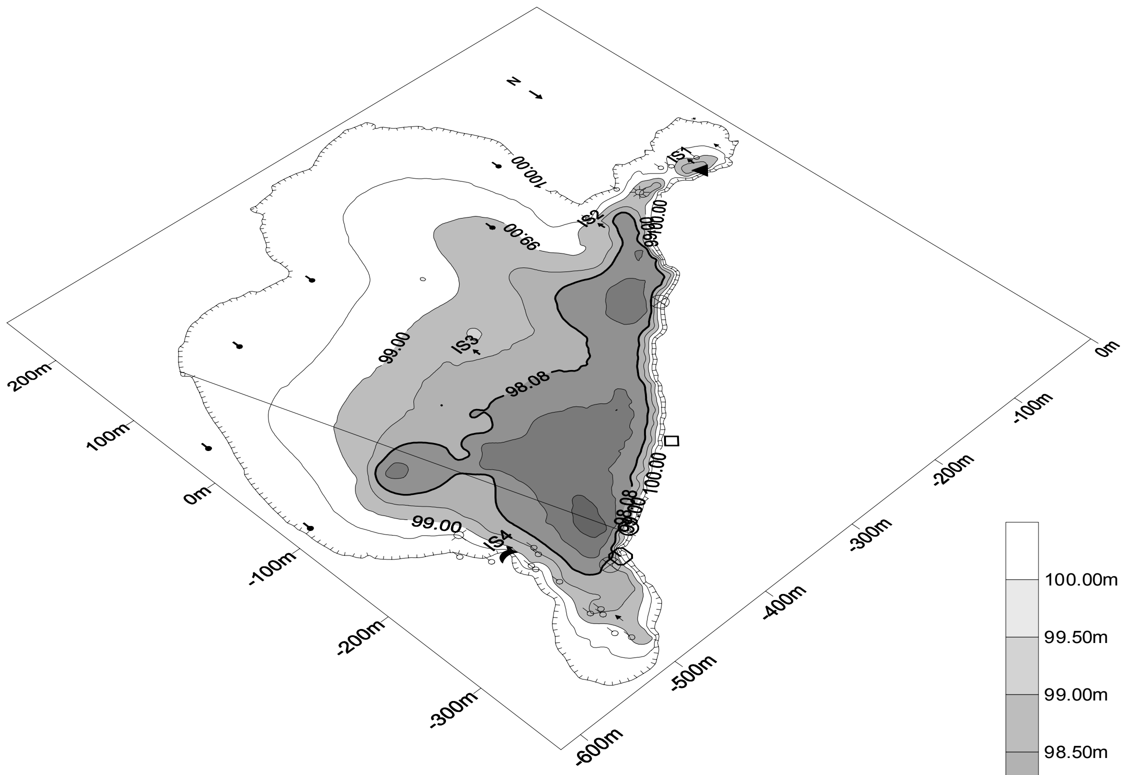
A20.4 Lunawewa

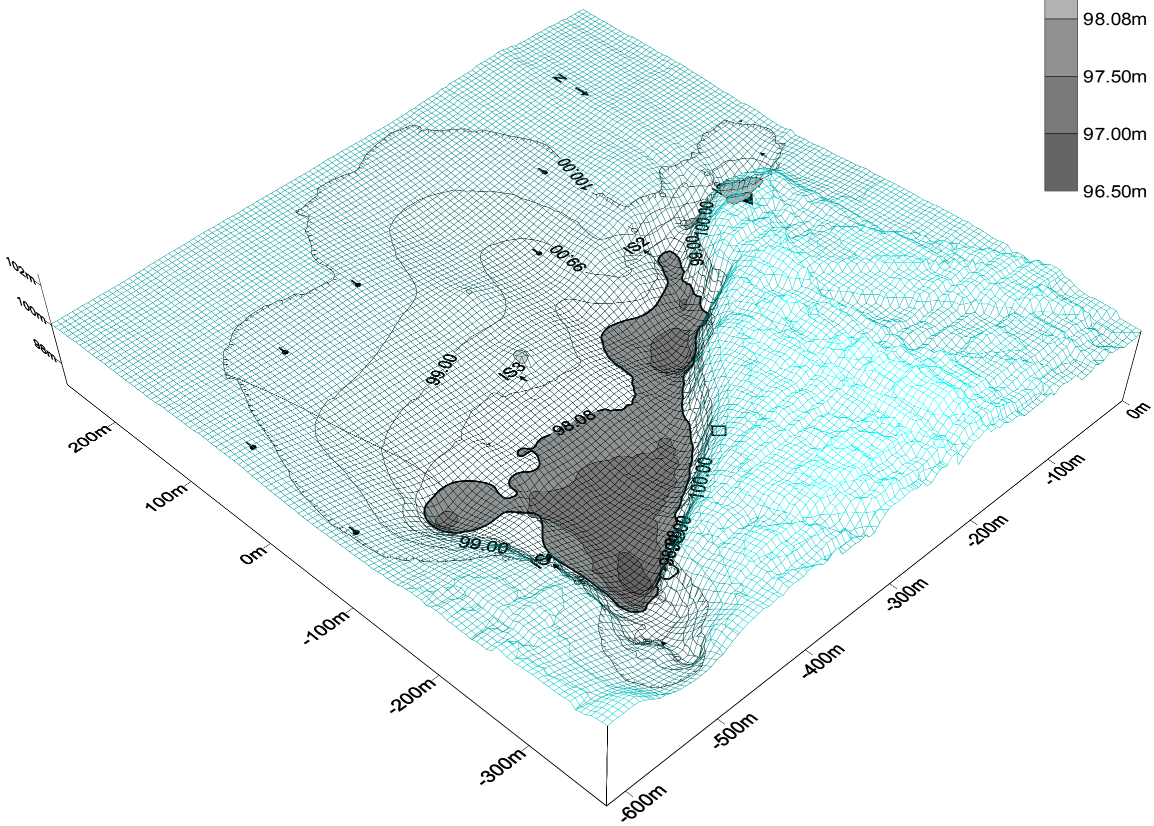


A20.5 Galenbindunewewa



A20.6 Lokahettiyagama





A20.7 Ihala Maradankadawala

Appendix 21 Seasonal water-spread area, irrigation and fishing practices in phase 2 intervention tanks Apr 2001 to Feb 2002

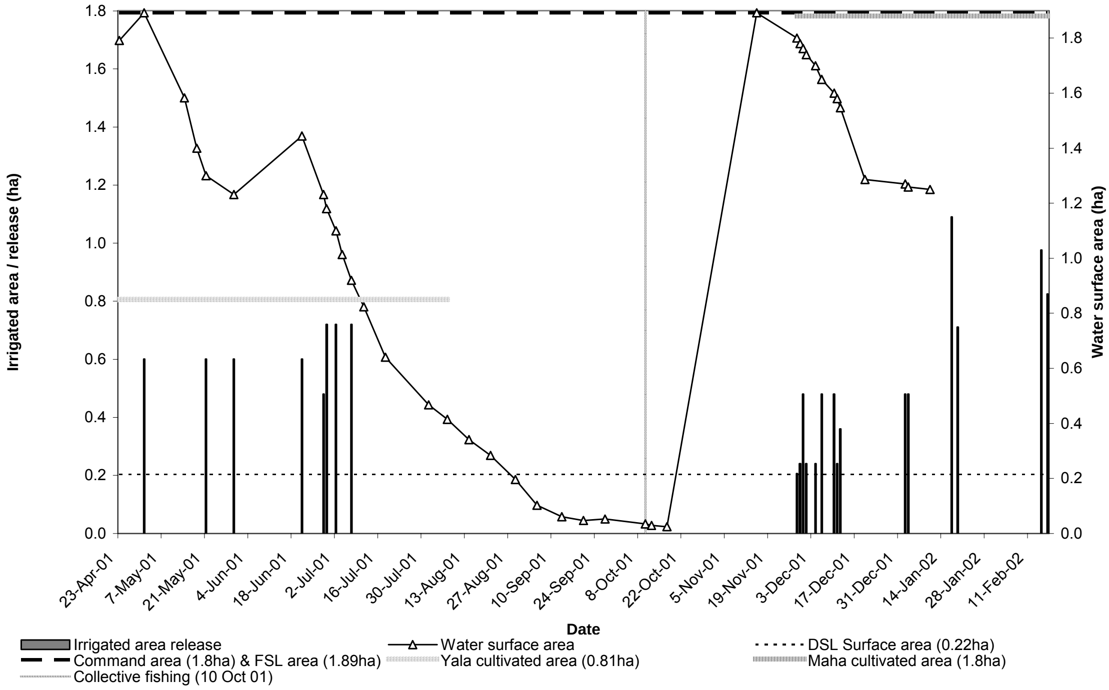


Figure A21.1 Karambewewa

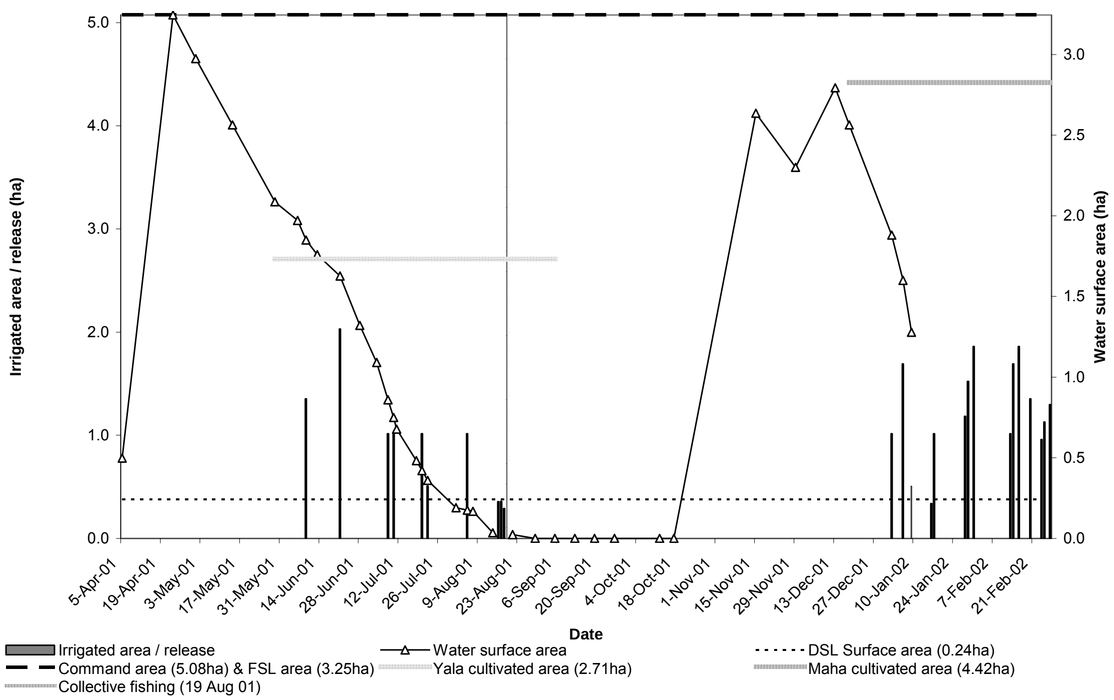


Figure A21.2 Serugaswewa

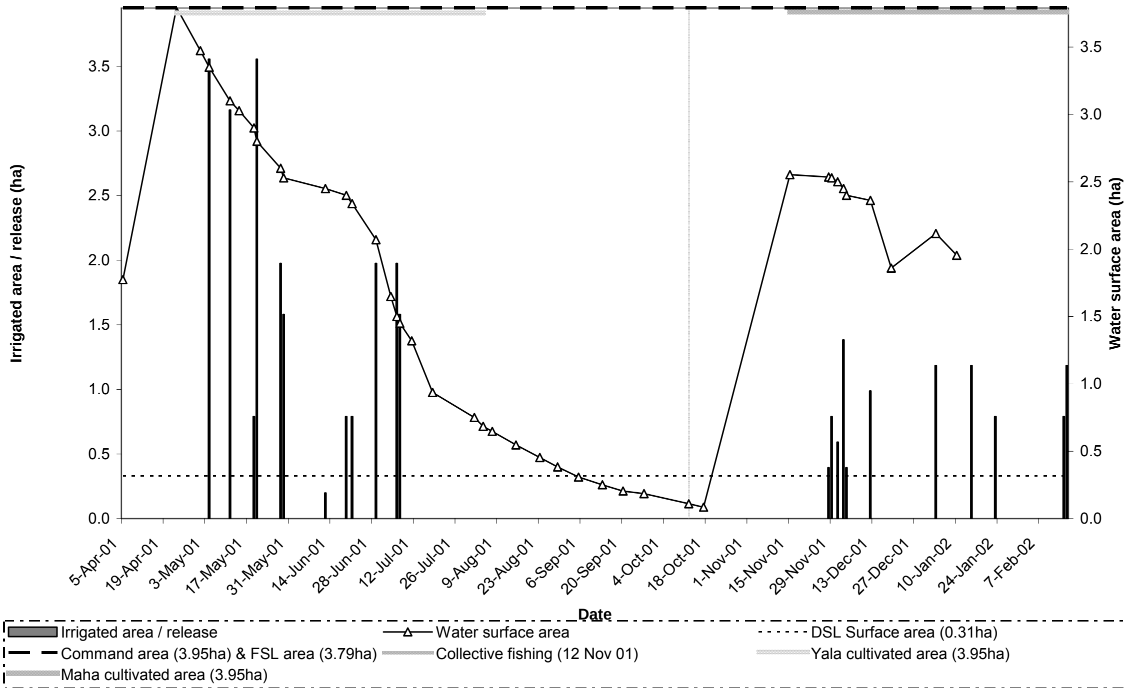


Figure A21.3 Lunawewa

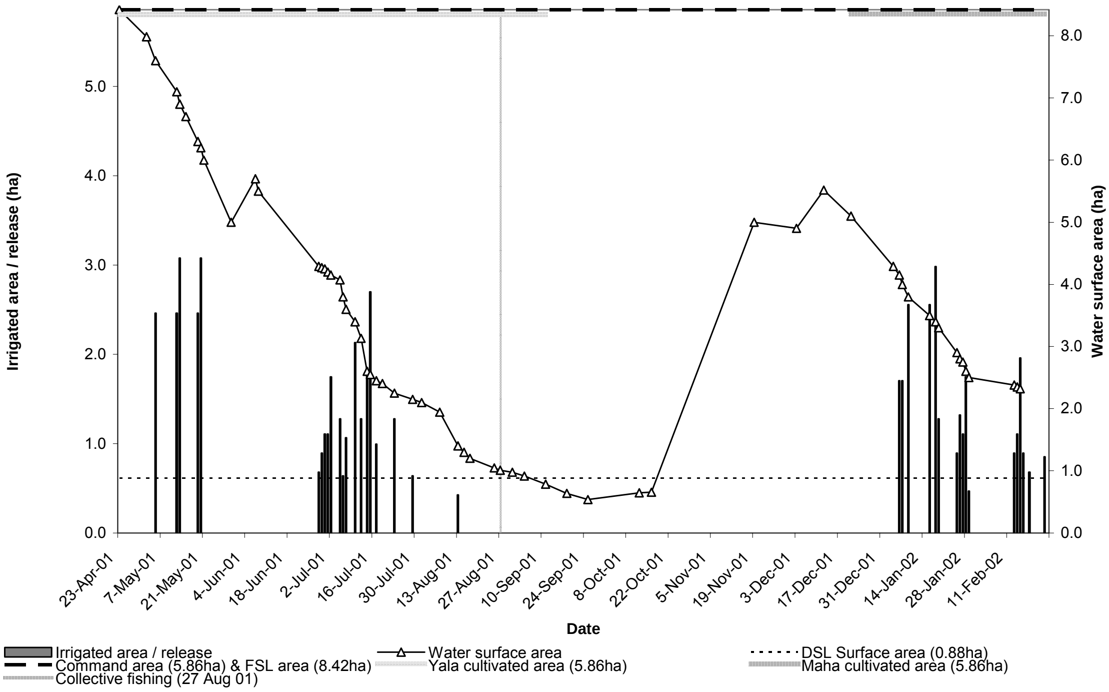


Figure A21.4 Galenbindunewewa

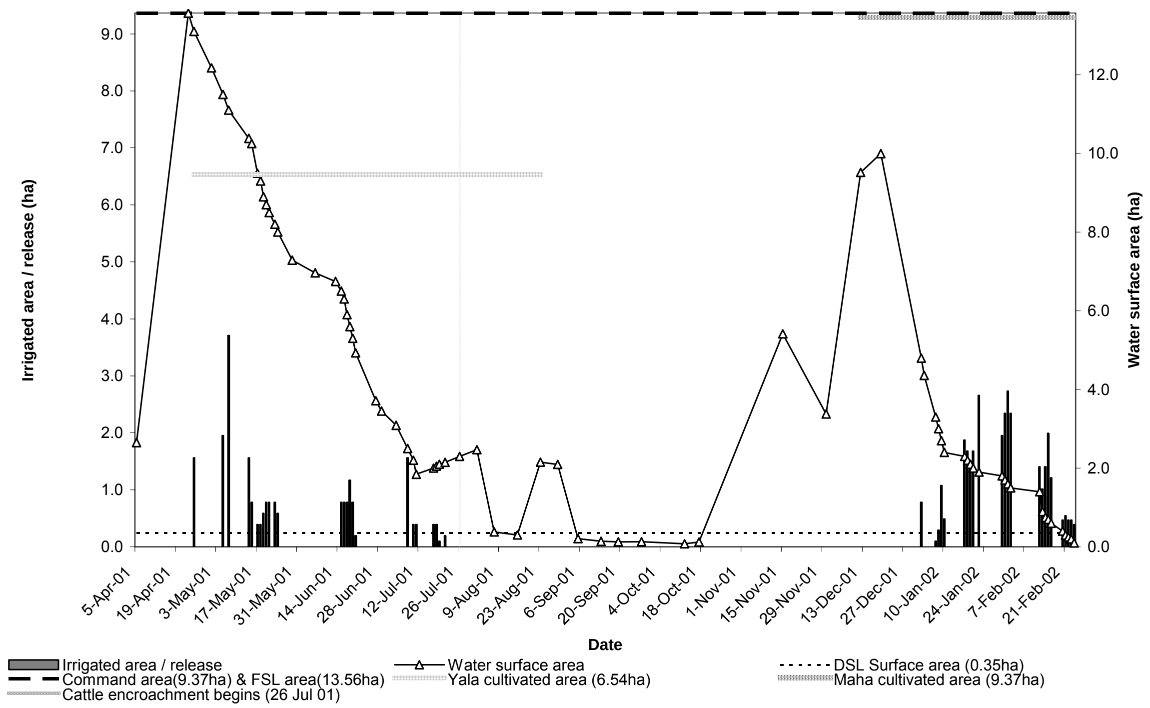


Figure A21.5 Lokahettiyagama

Appendix 22 Phase 2 tank photographic water storage profiles Mar to Nov 2001

29 March 01

2 May 01 - one week post FSL

29 June 01

21 September 01

19 October 01 - residual water-spread

14 November 01 - onset of NE monsoon

A22.1 Karambewewa

29 March 01

2 May 01

21 May 01

24 July 01

21 August 01

21 October 01 – residual storage

A22.2 Serugaswewa

2 May 01 - FSL

29 June 01

26 July 01

31 August 01

21 September 01

19 October 01 - residual storage

A22.3 Lunawewa

24 April 01 - FSL

29 June 01

25 July 01

6 September 01

13 September 01 – residual water-spread

30 November 01 Onset of NW monsoon

A22.4 Galenbindunewewa

29 March 01

21 April 01 FSL

29 June 01

31 August 01

19 October 01 – Showing areas excavated for bund repairs

14 November 01

A22.5 Lokahettiyagama

A21.6 Pahala Giribawa September 2003

A21.7 Gurulupitigama 25 7 01 (from bathing steps - with fringing *Salvenia molesta* cover)

A21.8 Ihala Maradankadawala September 2003 – (with dense *Nelumbum nucifera* cover)

Appendix 23 Principle macrophytes and their uses, in village tanks of Giribawa and Anamaduwa by habitat class.

Latin name and class	Local name	Status	Local uses
(1) Emergent			
Panicum maximum		Invasive	Fodder/ grazing – all livestock
Syperus pulcherimus	*lula wana*	Endemic	Fodder/ grazing – all livestock
Ikeria asteracantha spinosa	*ikeria*		Medicinal
Eclipta prostrata		Endemic	Non
Althernanathera sessilis	*mukunewende*	Endemic	Food, medicinal
Nelumbium nucifera	*nelum*	Endemic	Ceremonial, pasture (water buffalo), fodder (pigs)
Japonica arpatica	*kankun*	Invasive	Food
(2) Floating leaf			
Nymphaea pubescens	*olu*	Endemic	Food (tubers), ceremonial, pig fodder
Nymphaea nouchali	*manil*	Endemic	Food (tubers, seeds), ceremonial
Aponogeton crispus	*keketiya*	Endemic	Food, medicinal
Mimosa Sp.	*nidi kumba*	Endemic	Pasture
(3) Submersed			
Hydrilla parsi		Endemic	Non
(4) Free floating			
Salvinia molesta	*salvinia*	Invasive	Goat fodder (dried)
Pistia stratoites		Invasive	Fodder
Eichornia crassipes	*Japan jabora*	Invasive	Goat fodder (dried)
Azolla Sp.		Invasive	Non

Appendix 24 Fortnightly household livelihood monitoring survey sheet (administered Oct 00 to Nov 01)

1. Household information					
Database Rec No.		Name of household head			
Household code:		Respondent name			
Visit serial No.		Relation to HH			
Date this visit		No. resident/ absent/ guest			
Date last visit		Reln to HH absentees/ guests			
Days since last visit		Reason(s) for absence/ visit			
Enumerator(s)		Likely time of absence/ visit			

2. Household consumption and expenditure during week prior to interview									
2.1 Meal sharing									
No meals / day		No shared in meals/wk		From whom		No shared out-meals/wk		To whom	
2.2 Household food consumption and sources									
	Species/ varieties	Mark-eting	From Where/ Whom?	No Purchases /Wk	Total kg or Units /Week	No meals/ week	Rs/kg or unit	Fish/kg (SML)	Who Does / Doesn't consume
Inland fish									
Marine fish									
Dried fish									
Wild game									
Other meat									
Vegetable									
Dairy									
Eggs									
Own Produce									

2.3.Credit terms for food items? ____

2.4 Fresh fish available in village (Days/Week): A. Inland ____________ B. Marine _________

3. Other household/ business/ agricultural expenditure; total since last visit?			
Item	Source	Cost Rs	Comments

4. Household labour income & details of subsistence activities; total since last visit?
(Ar = Army, Ba = Baking, Bo = Boutique owner, BM = Brick Making, Bn = banking, BS = Blacksmith, Ca = Carpenter, CoA = Coolie Agric, Ch = *Chena* cult, HG = Home garden cult, Ir = Irrigated cult, Ma = Mason, Mi = Miller, Po = Police, Q = Rock Quarrying, SE = Sand Extraction, TE = Timber Extraction, TS = Timber Sawing. TV = Two-wheeler Vendor)

C1. Income labour	Who	Where	Km	Days	Rs/Day	Total	Comments
C2 Delayed Inc. Lab	Who	Where	Km	Days	Comments		
C3 Subsistence Lab	Who	Where	Km	Days	Purpose	Comments	

NB: B3: Wild animals and fish are considered in B1. Aquatic plants , firewood etc should be included in C3

5. Household benefits, savings and credit, total since last visit?

D1 Benefits	Who	Total (Rs)	Comments
Samurdhi/ Janasaviya			
Pension			

D2 Credit

Who	Purpose	Source	Rs	Loan time	% APR	Comments (i.e. tied)

D3 Savings
(Se = Seetthu, SaB = Samurdhi welfare saving, SaG = Samurdhi group, PA = Private Account)

Type	Who	Deposit Rs	Frequency	Seettu No. Members	Member details (location, gender)

6. Livestock Grazing; average since last visit?

Type	Nos	Ownership	Where grazed	Hrs/ day grazed	Dietary supplements / fodder?	Off –take Nos	Off-take returns	Other benefits/uses
Cattle								
Buffalo								
Goats								
Pigs								
Poultry								

7. How do you currently use water resource; frequency since last visit?

Uses	Name/ location?	Type of water body	Freq/ wk	Who	Perceived user conflicts?	Has usage changed recently If so – reason for changes?
Bathing						
Washing						
Irrigation						
Fishing						
Livestock						
Consumption						

NB. Other occasional uses include: Brick Making, Cadjan retting, Business extraction etc.

8. Collective Management Activities/Institutional meetings & role; total since last visit?

Type	Date	Who	Type of participation	No HH present	From where	Comments – activities planned, undertaken

9. Semi structured check-list notes:

Appendix 25 Household participatory impact monitoring and evaluation (PIM) survey sheet (administered Oct to Nov 2001)

A Household Information

HH Code		Respondent (s)	
Date		Reln to HH	
Enumerator		Location	

B Summary of participation

Type of fishing	B.1 Staggered – Pre Spill			B.2 During Spill		
Who						
No Days & When						
Gear(s) & source						
Location (tank)						
Where in tank/when						
	Self Caught	Gifted/Sold/ Bought (Whom)		Self Caught	Gifted/Sold/ Bought (Whom)	
		In	Out		In	Out
Snakehead kg						
SH size range						
Tilapia kg						
Ti size range						
SIS						

Historic changes? ______________________________ _________________________

Type	B.3 Staggered Post Spill			B.4 Collective			B.5 Post Collective		
Who									
Days									
Gears									
Locn									
Where									
	SC	Gifted/Sold/Bought (Whom)		Self Caught	Gifted/Sold/ Bought (Whom)		Self Caught	Gifted/Sold/Bought (Whom)	
		In	Out		In	Out		In	Out
SH									
Range									
Tilapia									
Range									
SIS									

Indicate use of SC fish. If gifted/sold/bought, indicate which and quantity, price/kg when and from whom as relevant

Historic changes? _______________ _____________________ __________________

C. Indicators of change

For your community (1) and household (2-6), what has changed as a result of the intervention compared to recent years?

	Change[1]	Rank[2]	Rank[3]	Indicator(s)[4] & comments
1 Social cohesion				
1.1 Inst Strength				
1.2 Conflict other uses				
1.3 Internal participation				
1.4 External participation				
1.5 Water Distribution				
1.6 Yield Distribution				
2 Water management				
2.1 Water quantity				
2.2 Water quality				
3. Food Security				
3.1 Species composition				
3.2 Species quantity				
4. Income generation				
5 Recreational activity				
6 Knowledge / Awareness				

[1]Worse (-), Better (+) or the same as before (0). [2]Rank the importance of any changes which took place whether –ve or +ve.
[3]Rank priority of desired changes (group indicators 1-5) [4]Define nature of change and how it may be measured

D. Future impacts

D1. Would you like to do this again or not (reasons)?

D2. What could we do to change / improve the system (reasons)?

D3 How could we encourage greater community involvement (reasons)?

Appendix 26 Household cultivation strategies and outcomes survey sheet (administered Aug to Nov 2001)

Review of irrigated and chena cropping strategies (before) and outcomes (after) for each family in the longitudinal household survey, during the previous maha and yala cultivation seasons

Respondent Name		Relationship to HH	
Name of HH		Enumerator	
HH code			
Date			

1. Extent of cultivation:

Season	Type[1]	Location[2]	Ac[3]	Access[4]	Comments[5]
Maha					
Yala					

1 IR = Irrigated, DLS: Dry Land Shifting, DLF: Dry Land Fixed/Upland, DLH Dry land HG.
2 Name of tank if irrigated, or location of *chena* / upland cultivation
3 Extent of area cultivated (acres).
4 Access: i. Owned by household, ii. Owned by extended family, iii. Share cropped, iv. Lease hold. v. Government
If not privately owned indicate location of 3rd party owner. Continue in comment section if necessary.

2. *Chena* Cultivation

Season	Access[1]	How access is affected?[2]	Fallow period[3]	Rotation[4]	Agro-chemicals applied
Yala					
Maha					

1Access – what is the distinction between fixed and shifting cultivation, i.e. Where are *chenas* in relation to tank (i.e. in catchment, alongside catchment or command)
2 How is access affected by family or other village relations, i.e. do farmers a) move freely and interchangeably between different *chena* lands, or b) restrict access to the household, c) Restrict access to the extended family.
3 How long do farmers fallow land between cultivation
4 Do farmers always return to the same area –, i.e. are they restricted in the acreage they have to rotate?
5What agri-chemical inputs typically applied..

3. Cropping Decisions. Complete Individual table for each of cultivation season

Season	Type	Crop(s) and acarage[1]	Why?[2]	Harvest[3]	Use of crops?[4]	Main Probs[5]
Maha						
Yala						

1 Crops selected for cultivation and individual acreage if mixed crops
2 Cropping Decisions; reasons for cultivation strategies selected, investigate both potential production and market orientated reasons
3 Actual or estimated harvest: Indicate whether total yield (i.e. bushels or kg) or estimated yield (i.e. bushels/ac)
4 Proportion kept for (household consumption), gifted, repaid for loans /sharecropping, or sold – if sold (or planning to sell) where and why?
5 Indicate main problems identified for each crop during the last 2 seasons – these may be production or market orientated.

4. Seed sources - for each 'season/type'

A Saved seeds

Season/type	Variety	From which season, how old?	Quantity	Success rate	Comments

B Commercial seeds

Season/type	Variety	Source	Quantity	Cost	extension	Comments

5. Historic trends in cultivation.

How have things got better – why?
How have things got worse – why?
Change of the strategies adopted

Season/type	Short term (last 2-3 years) and why?	longer terms (last 10 years) and why?	Highest yield	Lowest yield	Average yield

1 Under what conditions farmers experienced the highest and lowest yields (water availability, good seed etc and why is the difference).

6. Costs of this year's cultivation (complete for each season and type of cultivation:

Item	Season/type/location	Labor [1]	Freq [2]	Amount [3]	Rs [4]	Rs Tot [5]	Comments
Land Prep							
Clearing fields							
Ploughing							
Harrowing							
Fencing							
(Collective*)							
Seed Costs							
Fertilisers							
Weedicides							
Pesticides							
Hire costs							
Harvesting							
Threshing							
Transporting							
Milling							
Loan or lease terms							

[1] i.e. Self or hired labour
[2] Number of agrochemical applications, or days engaged in activity, hire, when during cultivation calendar.
[3] Amount applied per application indicated in previous column
[4] Cost per application (indicate units where relevant)

8. Extension

Decisions regarding cultivation, irrigation, agro-chemical applications,etc?

Type if information/decision[1]	From whome[2]	Comments

[1] Product instructions

[2]Neighbor/friends advice, extension officers advice, extension and any other help provided by AGS / extension officers.

9. Collective participation in or benefited from by household in different activities and decision making

Deciding on cultivation strategies	Who[1]	No of HH participation	Reciprocation In/Out	Out come[2]
Deciding cropping calender				
Land extent (bethma,etc)				
Crops(varities,duration)				
Irrigation				
Agro chem applications				
Purchasing agrichemicals/seeds				
Field clearing and burning				
Drainage canals				
Ploughing / harrowing land				
Sowing				
Applying fertilisers				
Applying weedicides/pesticides				
Weeding				
Transplanting				
Irrigating				
Guarding fields				
Harvesting				
Making hay rigs				
Threshing				
Transporting				
Milling				
Selling harvest				

[1]Who in the family (or extended family) participates in cultivation activities (relation to HH), neighbors, friends, and institutions

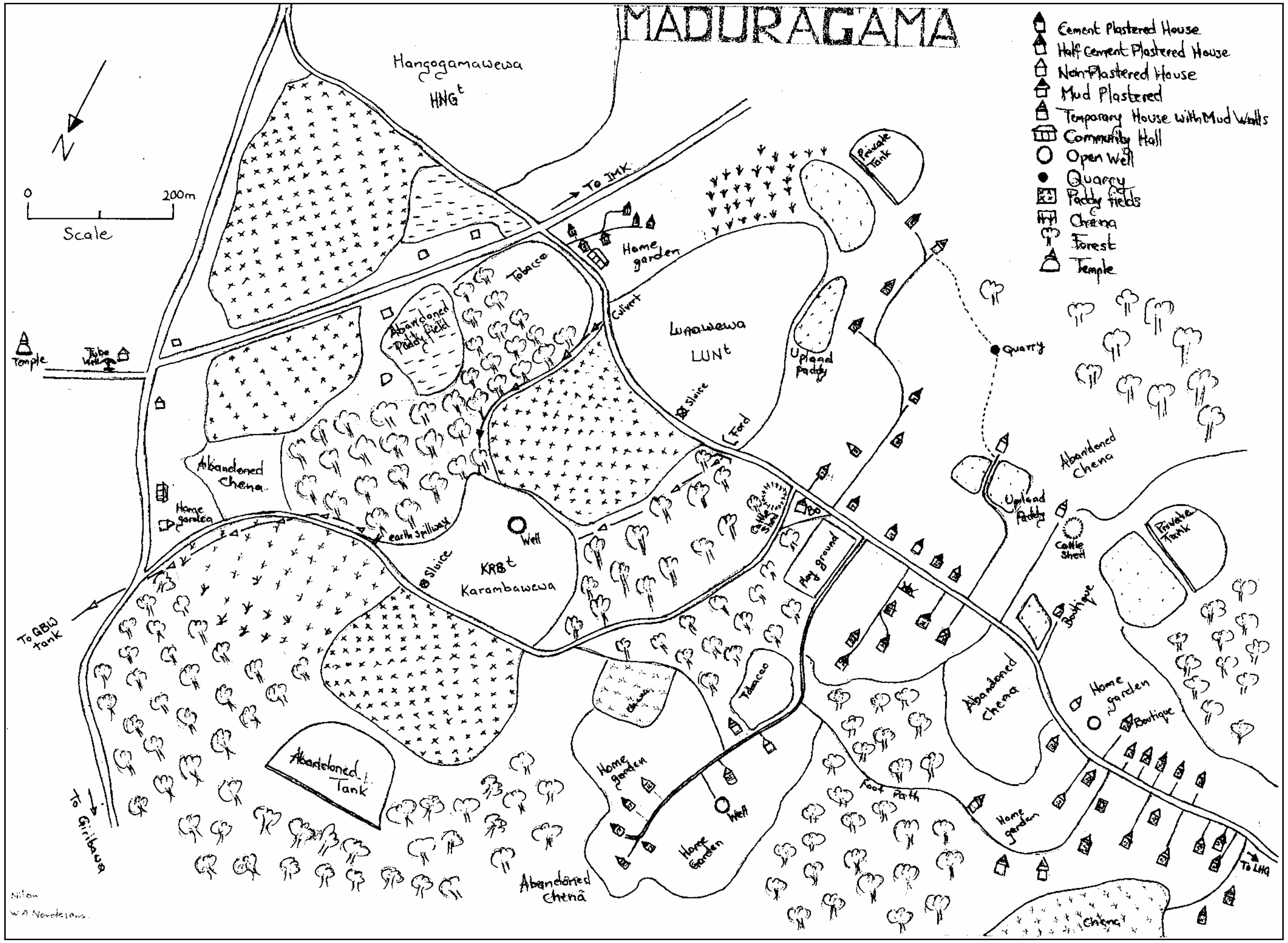
[2] Any problems, conflicts, will they do again

(Distinguish between irrigated paddy and *chena* as necessary)

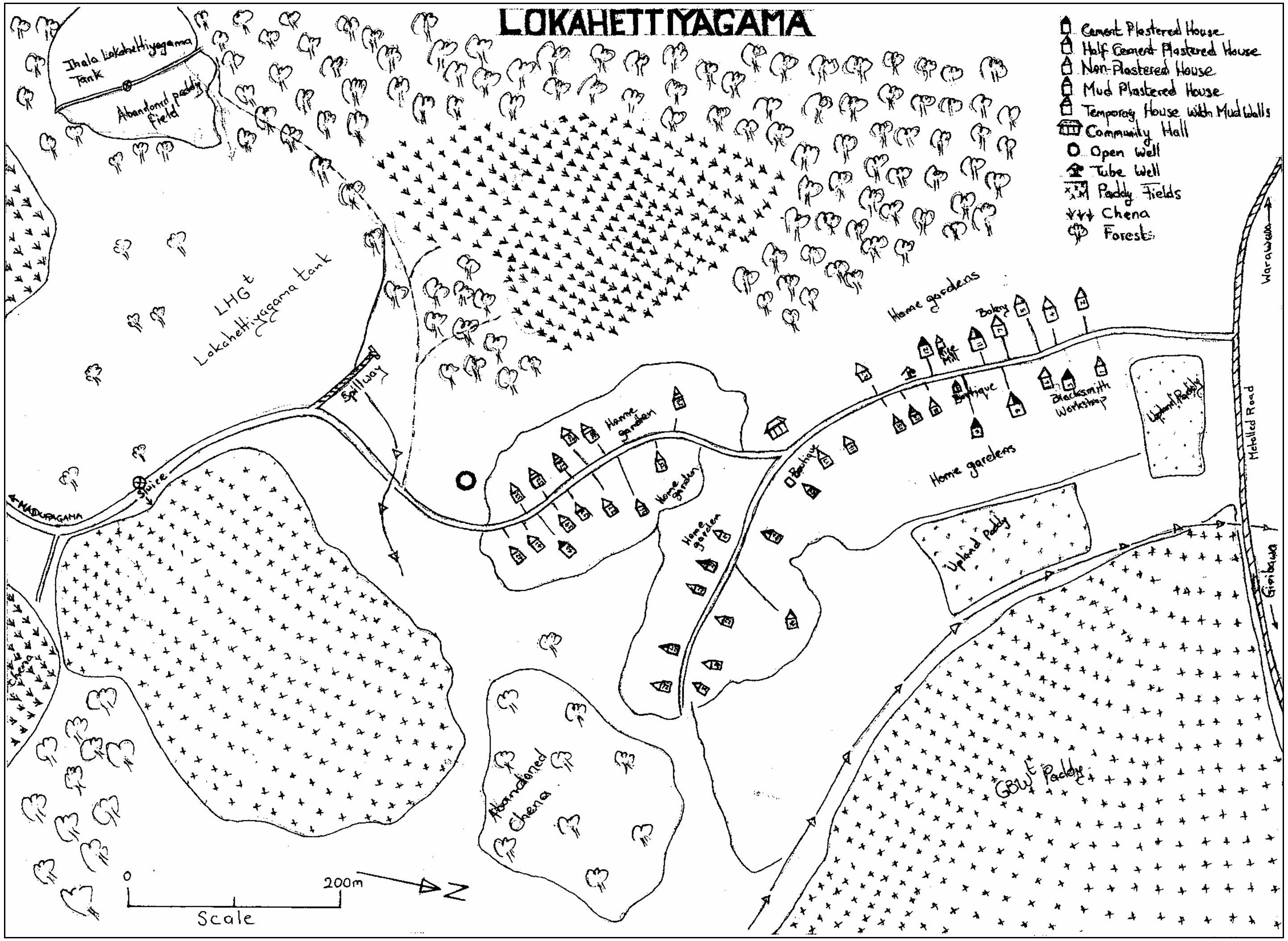
Appendix 27 Seasonal agricultural livelihood calendar and Inland fish market trends, Galgamuwa and Anamaduwa Districts, Sri Lanka, 1998-99 (Source: Interviews with farmers, fish producers and vendors). Note: +++ = greatest amount, - - - = lowest amount

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Weather cycle		**NE monsoon**						**SW monsoon & seasonal winds**				
Rainfall (total annual 950-1,350mm)												
Perennial tank water availability												
Cultivation season			*Maha* (main cultivation season)			Dry		*Yala* (minor cultivation season)				Main dry season
Paddy cultivation		Field preparation & sowing		**Irrigation**		Harvest	Field preparation & sowing		**Irrigation**	Harvest		
Dryland cultiviation	Sowing		Harvest				Fallow period				Field preparation	
Off-farm labour	++	++	++		+++	+++						+
Income availability	– – –	– –	+	– –	+	+++	++	+	+	–	– –	– – –
Inland fish supply												
Supply factors		NE monsoon - large fish rise Highest catch during spills		Max water spread - lowest catch				High water & winds impede netting			Lowest water – highest catch of small varieties	
Inland fish demand		++		+		++++ Harvest & New Year		++			+++ (Esp. for small varieties)	
Price of inland fish		+++	+	+++	++	++++		++			+	
Marine fish availability		++++					++				++ (Small varieties)	

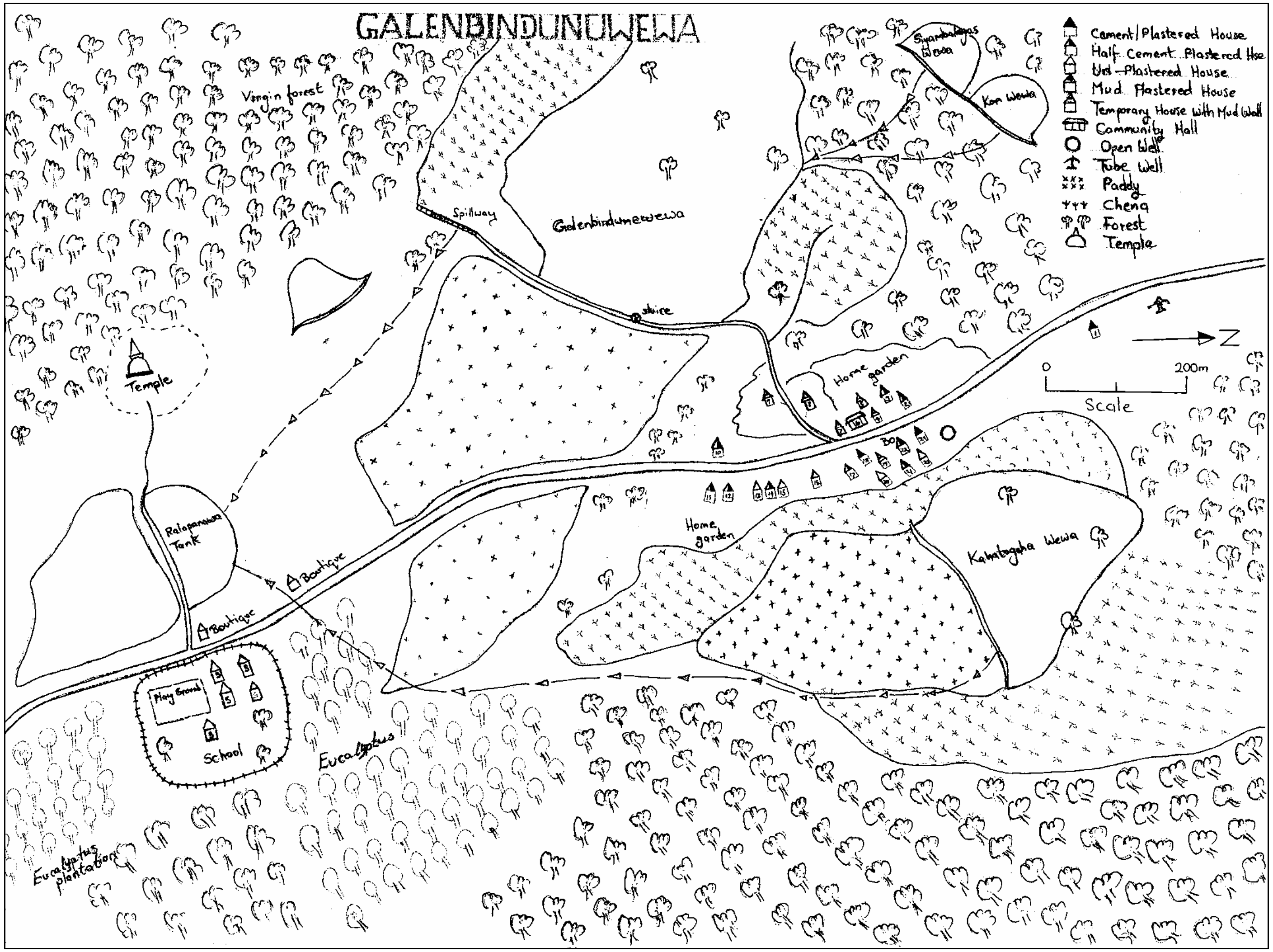
Appendix 28 Social maps of five intervention villages



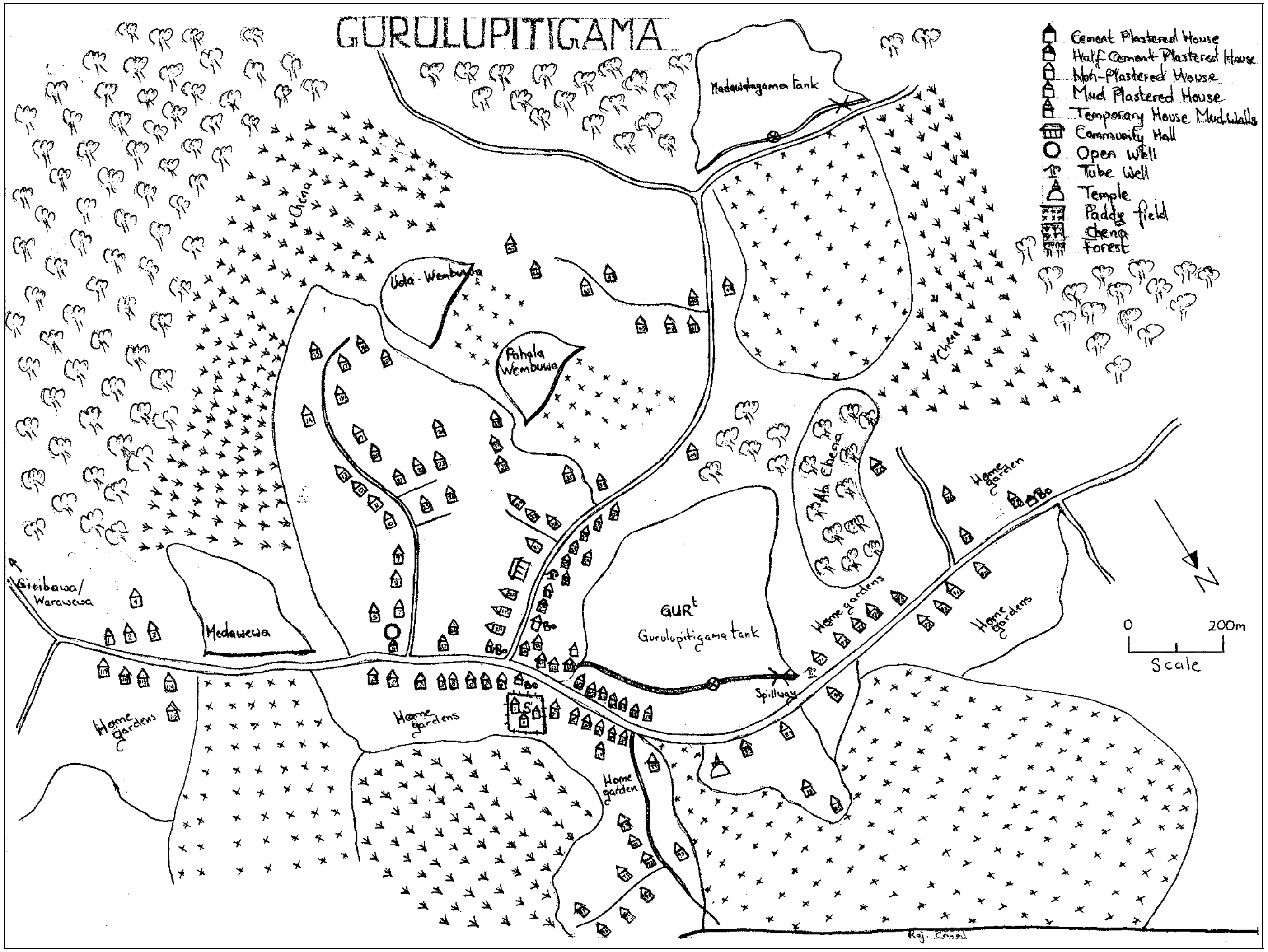
A28.1 Maduragama



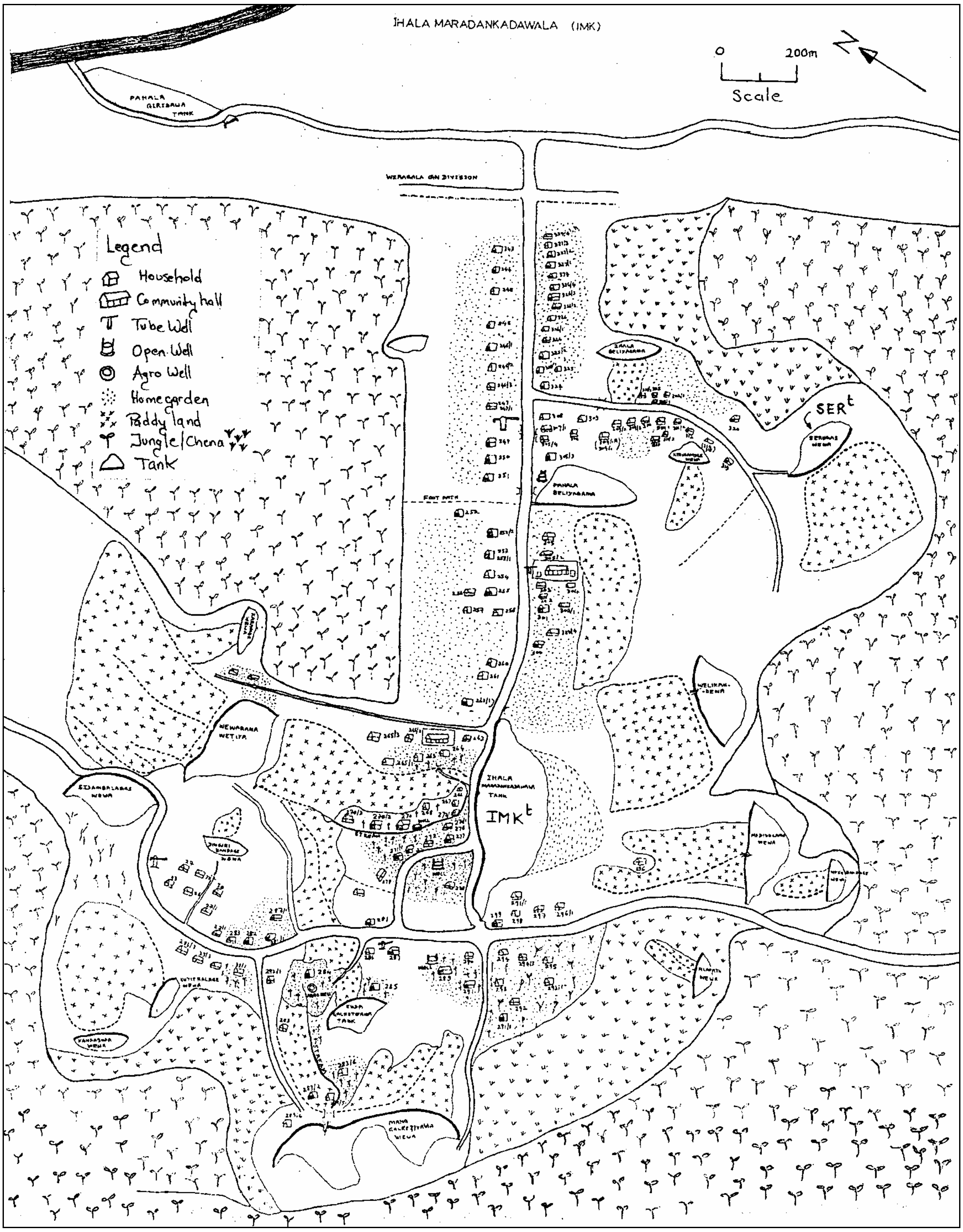
A28.2 Lokahettiyagama



A28.3 Galenbindunewewa



A28.4 Gurulupitigama



A28.5 Ihala Maradankadawala (drawn by the local *Grama Niladhari* resident in the village)

Appendix 29 Statistical analyses of household occupancy level by wealth rank and village location

A29.1 Results of factorial ANOVA on household occupancy with village and wealth rank as independent factors.

Tests of Between-Subjects Effects
Dependent Variable: No HH Members

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	84.195	14	6.01	2.91	.00
Intercept	3608.660	1	3608.66	1743.54	.00
VILLAGE	50.369	4	12.59	6.08	.00
WEALTHCD	12.513	2	6.26	3.02	.05
VILLAGE * WEALTHCD	12.820	8	1.60	.77	.63
Error	689.219	333	2.07		
Total	6584.000	348			
Corrected Total	773.414	347			

a R Squared = .109 (Adjusted R Squared = .071)

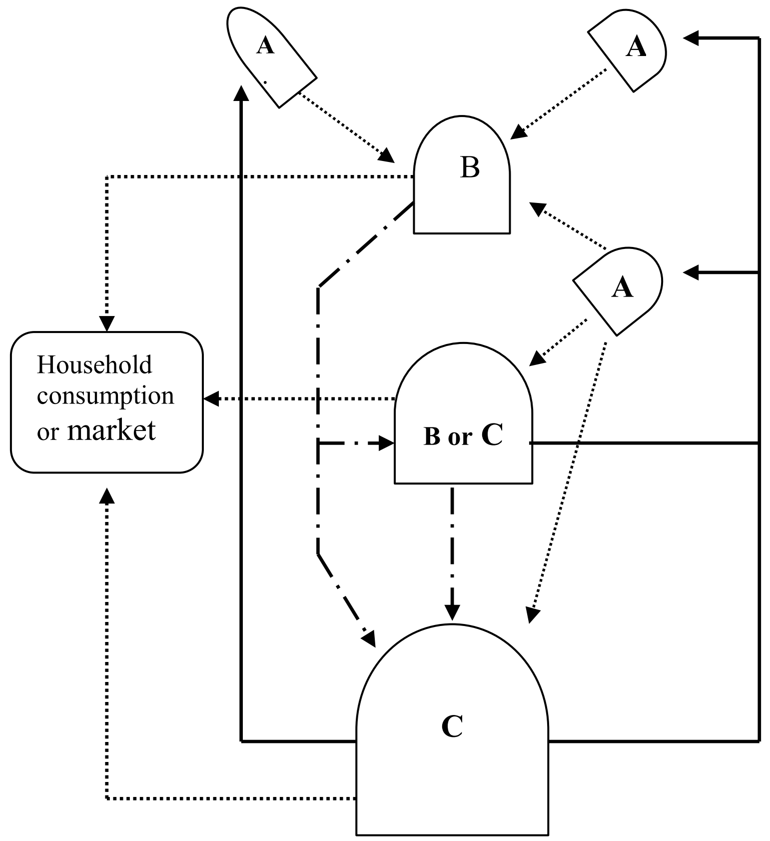
29.2 Tukey's post-hoc comparisons of occupancy by village for five intervention sites.

Multiple Comparisons
Dependent Variable: No HH Members
Tukey HSD

(I) Village CD	(J) Village CD	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
GUR	IMK	-.2878	.19214	.565	-.8148	.2392
	LHG	-.3115	.24785	.718	-.9913	.3683
	MAD	-.8179	.24078	.007	-1.4783	-.1575
	GBW	-1.4689	.31652	.000	-2.3370	-.6008
IMK	GUR	.2878	.19214	.565	-.2392	.8148
	LHG	-.0237	.25212	1.000	-.7152	.6678
	MAD	-.5302	.24517	.197	-1.2026	.1423
	GBW	-1.1811	.31987	.002	-2.0585	-.3038
LHG	GUR	.3115	.24785	.718	-.3683	.9913
	IMK	.0237	.25212	1.000	-.6678	.7152
	MAD	-.5065	.29089	.410	-1.3043	.2914
	GBW	-1.1574	.35613	.011	-2.1342	-.1807
MAD	GUR	.8179	.24078	.007	.1575	1.4783
	IMK	.5302	.24517	.197	-.1423	1.2026
	LHG	.5065	.29089	.410	-.2914	1.3043
	GBW	-.6510	.35124	.345	-1.6144	.3124
GBW	GUR	1.4689	.31652	.000	.6008	2.3370
	IMK	1.1811	.31987	.002	.3038	2.0585
	LHG	1.1574	.35613	.011	.1807	2.1342
	MAD	.6510	.35124	.345	-.3124	1.6144

Based on observed means.
* The mean difference is significant at the .05 level.

Appendix 30 Envisaged fish movements in a tilapia-based, low-input, enhanced fishery with seed, grow-out and broodstock components demarcated at the watershed level (based on situation analysis in Danduwellawe & Pahala Diulwewa cascade systems of Puttalam & Kurunegala districts, NW Province)



Legend

Symbol	Key
A	Highly seasonal small tank; CPR[1] or private (Temple/farmer)
B	Semi-Seasonal village tank; CPR
C	Perennial village tanks (rainfed or system[2]): CPR
··········▶	Advanced fingerling movements from seasonal tanks
··········▶	Staggered food-fish production (to markets)
— · —▶	Dry season broodstock movements (maintenance)
——▶	Rainy season broodstock movements (in situ fingerling production)

[1] Common Property Resource.

[2] Lower tanks may also receive water from medium or major irrigation systems.

Note: The watershed level at which culture components are demarcated will depend on site specific constraints, in particular the seasonal characteristics of the various water bodies accessible to different communities.

Appendix 31 Checklist for monitoring of collective fishing events during phase 1 trials

- Conditions of tank at harvest (depth, WS encroachment, predation)
- Area fishing biases within the tank.
- Size of gears, and affect on participation / fishing methods
- Access, source, terms for loans for gears and effects on participation?
- Size/ species break down of catches.
- Fate and distribution of catches
- Participation: where, who, age, gender
- Multi-day collective fishing: Do participants change? Do they change during the day?
- Poaching from where? History
- Participation of villagers in fishing outside the village
- Do observed participant's fish regularly in the same tanks
- Anecdotal evidence of previous harvests and reasons.
- Other physical and social constraints to fishing.
- Institutional decision making and participation – how villagers informed.
- Cohesion and collaboration of different CBIs.
- Dates and enforcement of bans
- *Shramadana* events in village and participation – this year
- Access rules, adherence and enforcement potential.
- Integration of fishing with other uses/users of water
- No's bathing, where and current options
- Anecdotal evidence of management in previous years (inc. last date).
- Who relies mostly on the resource
- Cause of conflicts and relative importance compared to other NR conflicts
- Current availability of fish and potential impact of seasonal tank resource.
- Management of stocks for subsequent years (net sizes, stocking etc).

Appendix 32 Knowledge gaps and constraints to aquaculture in small-scale irrigation systems, identified during a secondary stakeholder workshop; Hotel Topaz, Kandy, 26-27 Nov 1998 (factors identified as researchable are emboldened)

Constraints	Knowledge gaps
1. Technical	
1. Seasonality and uncertain water availability* **2. Erratic fluctuations in water levels*** 3. Inadequate seed and fingerling production and capacity** 4. Availability of suitable species for stocking and timing of seed production* **5. Primacy of irrigation over fish-production**** **6.Compatibility of farming systems around tanks: overuse/ misuse of agro –chemicals and lack of organic inputs** **7. Lack of basin-level hydrological planning and integrated watershed management** 8. Poor tank and catchment maintenance resulting in siltation and loss of storage capacity*** 9. Poor understanding of pond management and harvest technologies*	**1. How to enhance and sustain natural fish breeding systems during the design and management of irrigation systems** 2. Appropriate technologies for the spawning and nursing at community level* 3. Management of self-recruiting fish populations in perennial tanks* 4. Appropriate technology for poor people / women to culture ornamental fish* 5. Polyculture of ornamental and food fish. 6. Rice -fish culture technology
2. Socio-economic	
1. Poaching** **2. Traditional subsistence mechanisms for managing aquatic production and lack of aquaculture tradition** **3. Population pressure and increasing common property resources conflicts** **4. Poor co-ordination between different uses of water** 5. Access to start-up capital	**1. Poor understanding of cast, ethnicity, gender & religion in relation to CPR access** **2. Seed and food fish marketing and production networks.** **3. Consumer preferences for inland fish varieties**** 4. Compatibility of different aquaculture options with existing portfolio of income generating activities at community and household level
3. Institutional	
1. Lack of technical extension capacity. **2. View of property rights which ignores informal normative rights** 3. Poor capacity to implement and enforce laws when co-management is necessary 4. Poor definition and overlap of responsibilities between Govt. agencies results in conflict of interest & turf fighting**	**1. Lack of baseline production statistics** **2. Inconsistent definitions and poor inventory of small scale irrigation systems: variety and quantity*** **3. Participatory techniques to promote community management***
4. Biological	
1. Encroachment by aquatic plants** 2. High predation pressure* 3. Availability of suitable species for local niches especially macrophagous varieties	**1. Suitability of indigenous fish species for different water bodies*** 2. Potential for spread of communicable disease through stocking: diagnosis, prophylaxis and treatment

* Asterisks denote the frequency with which constraints were cited by four different stakeholder groups:
* = 2 citations, ** = 3 citations etc.

Appendix 33 Inventory of indigenous inland fish species used for human consumption (Sources, primary stakeholder workshops and field observations NW Province, Pethiyagoda 1991, 2002 Siriweera 1986, De Silva 1988a.

Latin name / Family	English name	Sinhalese name	Main Diet	Max. Size (cm)	Status	Tank Habitat	Comments
Cyprinidae							
Rasbora daniconius	Striped R.	*Dandiya*	Z	8-15	I/C	S,P	'A poor persons meal' (also *R. caverri*)
Amblypharyngodon melettinus	Tank Sardine/ Silver carplet	*Wewa Salaya*	P,D	10	I/C	S,P	Trash' fish often sun dried
Puntius chola	Swamp barb	*Podi pethiya*	P	8-15	I/C	S,P	Occasionally aquarium
Puntius dorsalis	Long snout B.	*Kata pethiya*	P	25	I/C	P	Occ. aquarium
Puntius sarana	Olive barb	*Mas pethiya*	P,Z	30	I/C	P	Bony & decomposes rapidly. Occ. Aquarium
Puntius filamentous	Filamented B.	*Dankola P.*	Z	10-12	I/C	S,P	Bait fish, Aquarium
Labeo dussumieri,	Common L.	*Hiri kanaya*	P,Z	40	I/D	P	Important food fish now In decline.
Labeo porcellus	Orange fin L.		P	35	I/En	P	Important food fish now endangered
Tor Khudree	Mahseer	*Leyla*					
Cichlidae							
O. mossambicus	NA	Theppili	P,Z	35	Ex/C	S,P	Most important food fish
O. niloticus	Nile tilapia	Thilapiya	P,Z	40	Ex/C	S,P	Important food fish
Etroplus Suratensis	Green chromide	*Mal koraliya*	M,Mc	30	I/C	P	Important food fish. Brackish and inland waters
Belontidae							
Trichogaster pectoralis	Snake Gourami	*Japan corrali*	P,M,Z	25	Ex/C	S,P	Introduced 1950's, prolific breeder, air breather
Anabantidae							
Anabas testudineus	Climbing perch	*Kavaiya*	D,Z,S	15	I/C	S,P	Important food fish. Ambulatory, air breather
Gobiidae							
Glossogobius giuris	Bar eyed goby	*Weligouva*	Pv,Z	25	I/C	S,P	Obligate predator, estuarine origin
Ophiocephalidae							
Channa striatus	Snakehead	*Loola*	Pv	40	I/C	S,P	Important food fish. Ambulatory, air breather

Latin name / Family	English name	Sinhalese name	Main Diet	Max. Size (cm)	Status	Tank Habitat	Comments
C. marulius	Giant SH	*Gang ara*	Pv	80	I/LC	P	Ambulatory, air breather
C. gachua	Brown SH	*Parandal kanaya*	Pv,Z	20	I/C	S	Ambulatory, air breather, rarely consumed
C. punctata	Spotted SH	*Madakanaya*	Pv,	20	I/C	S	Ambulatory, air breather, rarely consumed
Siluridae							
Wallagu attu	FW shark	*Wallaya*	Pv	L	I/LC	P	In decline
Ompok bimaculatus	Butter catfish	*Pena walaya*	Pv	40	I/LC	P	
Bagridae							
Mystus vittatus	Dwarf catfish	*Ankuta*	Z,Pv	20	I/C	S,P	Very occasional food fish. Survives desiccation by unknown method.
Mystus keletius	Yellow catfish		Z,S	18			
Clariidae							
Clarias brachyasoma	Walking catfish	*Magura*	Pv,S	50	Ed/LC	S,P	Scavenger, mostly Wet-Zone, air breather
Heteropneustidae							
Heteropneustes fossilis	Stinging catfish	*Hunga*	Pv,S	30	I/LC	S,P	Food fish now in decline, scavenger, air breather
Mastacembelidae							
Mastacembelus sp.	Spiny eels	*Theliya*	Z,S	60	I/LC	S,P	In decline, two species, food fish. Occ. aquarium
Anguillidae							
Anguilla sp.	Eels	*Anda*	Z, Pv	120	I/C	P	2 Sp: *A. bicolor, A. nebulosa*

Notes:
[1]Diet: P = Phytophagous, Z = Zooplanktivorous (inc. insects), M = Macrophagous, Pv = Predator & piscivore, Mc = Molluscs, S = Scavenger
[2]Status: I = Indigenous, Ex = Exotic, Ed = Endemic, En Endangered, R = Rare, LC = Less common, C = Common.
[3]Tank: S = Seasonal, P = Perennial

Appendix 34 Maduragama Fishermen's Socitey Constitution 26 1 01

Meetings: General meeting once every 3 months, executive meeting once per month.
Membership fee: Rs 10/ member – This should be paid within 1 month in order to become a member.
Management and cleaning of the tank: Control of Olu through *Shramadana* activities
Fish Varieties: Snakehead and tilapia to be stocked
Enforcement: To be the responsibility of the executive committee
Access: Full-members of the society only shall be allowed to fish
Fishing Gears: Nets and Karak
Sanctions to be taken against anyone disobeying rules
First a warning will be given. After the Second offence the *Grama Niladhari* shall be informed and finally the police
Selling of fish: Other villagers requiring fish should receive them at a wholesale price based on current market valuations. Only if there is surplus fish should sales be made to external vendors. A proportion of profits should be donated to the DDS (level to be fixed).
Restocking of the tank a second time to be discussed after future assessment.

All present agreed to these rules.

Signed: AWA Dharmasena (Secretary) WA Sisirakumara (President).

Membership list to be appended
Organisation has not been registered as of May 2001.

Appendix 35 Report of the first Galenbindunewewa Fisherman's Society meeting 21 11 00 (facilitated with support of CARE International staff)

Time 9.30AM
Present: Pres of FO; Mr Gamarale.
After discussion officer bearers were elected;
Mr Premeratne was nominated for Pres by Keerashinghe, seconded Mrs Nandawathi.
Mr Samarasisi was nominated for Sec by Mr Marasinghe, seconded Mr Suhahami
Mr PM Premadasa nominated as Treasurer, seconded Mr Nawaratne

Constitutional meeting: 27 11 00.
President explained requirement of constitution:
Navaratne: We have to combine FO and FS and have to manage the tank jointly. First activity will be bund cleaning. Permission to be obtained from the organisation for any fishing activity. Will stock tank 1x per year, meet 1x per month and collect Rs as membership fee. Violators of these rules will be denied irrigation water during the cultivation period. Anyone caught poaching or using force to catch fish will be fined or the help of the Puttalam police will be obtained. The monthly minutes will be sent to the Halwatha (Chillaw) agrarian services centre.

All members agreed to the above terms and conditions with signature.
Tres: Vote of thanks

Signed Samarasiri. Sec

Members of GBW Fishing Society

K Premeratne	W Vijaratne	K Kirimenike
NM Samarasiri	W Nawaratne	NM Sudumenike
PM Premadasa	KM Samara	P Piyaratne
NM Ukubande	A Jayawardene	P Piyadasa
NM Puncha	S Marasinghe	TW Karnaratne
NM Gamarale	S Abeyasinghe	NM Nihal Nawaratne
NM Punchibande	HSB Marapuliya	Sunil Priyanthe
W Sudahami	NM Keeritisinghe	Desanayake
W Gunaratne	W Palitha	A Tilakeratne

Notes:
All are household heads
19 and 20 are the only female headed house holds (divorced)
21, 22, 25, 26 are the only non FO members, as own no land under GBW. These farmers have lands under other tanks except 26 who is an external settler.

Appendix 36 Results of log-linear analysis on PIM 'repeat intervention?'

Table A36.1 'Best' log-linear model observed, expected frequencies and residuals for (1) village (LHG and GBW), (2) wealth rank and (3) gender

Factor	Code	OBS count	EXP count	Residual	Std Res
VILLAGE	Galenbindunewewa				
GENDER	Male				
WEALTH	Better-off	3.0	3.0	0.00	0.00
WEALTH	Medium/poor	5.0	9.3	-4.33	-1.42
GENDER	Female				
WEALTH	Better-off	2.0	0.0	2.00	0.00
WEALTH	Medium/poor	4.0	4.7	-.66	-.31
VILLAGE	Lokahettiyagama				
GENDER	Male				
WEALTH	Better-off	3.0	3.0	.00	.00
WEALTH	Medium/poor	11.0	4.2	6.76	3.28
GENDER	Female				
WEALTH	Better-off	1.0	.0	1.00	.00
WEALTH	Medium/poor	6.0	7.8	-1.77	-.64

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Goodness-of-fit test statistics
   Likelihood ratio chi square =    10.41223    DF = 6  P =  .108
            Pearson chi square =    11.28764    DF = 6  P =  .079
```

Table A36.2 'Best' log-linear model observed, expected frequencies and residuals for (1) village (LHG and GBW), (2) wealth rank and (3) age class

Factor	Code	OBS count	EXP count	Residual	Std Res
VILLAGE	Galenbindunewewa				
WEALTH	Better-off				
AGECLASS	< 40	3.0	3.0	0.00	0.00
AGECLASS	≥ 40	2.0	0.0	2.00	0.00
WEALTH	Medium/poor				
AGECLASS	< 40	8.0	10.7	-2.69	-.82
AGECLASS	≥ 40	1.0	0.0	1.00	0.00
VILLAGE	Lokahettiyagama				
WEALTH	Better-off				
AGECLASS	< 40	1.0	0.0	1.00	0.00
AGECLASS	≥ 40	3.0	3.0	0.00	0.00
WEALTH	Medium/ poor				
AGECLASS	< 40	10.0	7.3	2.67	0.99
AGECLASS	≥ 40	7.0	7.0	0.02	0.01

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Goodness-of-fit test statistics
   Likelihood ratio chi square =     1.61416    DF = 6  P =  .952
            Pearson chi square =     1.64937    DF = 6  P =  .949
```

Table A36.3 'Best' loglinear model observed, expected frequencies and residuals for (1) village (LHG and GBW), (2) wealth rank and (3) km from tank

Factor	Code	OBS count	EXP count	Residual	Std Res
VILLAGE	Galenbindunewewa				
WEALTH	Better o				
KMTANK	< 0.5km	2.0	3.0	-1.00	-0.58
KMTANK	> 40	3.0	0.0	3.00	0.00
WEALTH	Medium/ poor				
KMTANK	< 0.5km	8.0	6.7	1.35	0.52
KMTANK	> 40	1.0	8.9	-7.87	-2.64
VILLAGE	Lokahettiyagama				
WEALTH	Better-off				
KMTANK	< 0.5km	1.0	0.0	1.00	0.00
KMTANK	> 40	3.0	2.0	1.00	0.71
WEALTH	Medium/ poor				
KMTANK	< 0.5km	8.0	5.5	2.45	1.04
KMTANK	> 40	9.0	4.9	4.07	1.83

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Goodness-of-fit test statistics

Likelihood ratio chi square = 11.09520 DF = 6 P = .053

Pearson chi square = 12.53981 DF = 6 P = .051

Appendix 37 Access® relational database

Contents

1. Cascade typologies
2. Longitudinal market survey Galgamuwa
3. Consumer preferences for fish and its substitutes
4. Village baseline surveys
5. Wealth ranking
6. Longitudinal household survey
7. Cultivation strategies survey
8. PIM survey
9. Test fishing
10. Collective fishing
11. Staggered harvesting