

**Potential for aquaculture within farmer-managed irrigation systems  
– Lessons learnt in Northwest Sri Lanka**

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**Background**

The following findings relate to a three year study in which a general overview of fish demand was placed in the context of seasonal tanks in the Dry Zone of Sri Lanka. Thirteen cascades in discrete locations over a wide geographical area (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 in three clusters, located in Puttalam and Kurunegala Districts, North West Province between 1999 and 2001. Preliminary farmer-managed trials took place with four communities (5 Tanks) in 1999/00. A second phase of modified trials took place with three new communities and one old (5 Tanks) in 2000/01. A fortnightly household livelihood monitoring survey, incorporating a participatory impact monitoring (PIM) component, was undertaken concurrently with the second phase of trials. This incorporated a total of 40 wealth stratified households in four communities in different watershed locations. This commenced with a detailed baseline survey and was implemented over 14 months. Other village level activities concurrent with the Phase 2 trials included a detailed longitudinal assessment of tank nutrient dynamics, hydrology (8 tanks) and fish yields (5 tanks). A detailed questionnaire assessing the outcome of the agricultural cropping strategies of the 40 monitoring households and PIM questionnaire investigating the fisheries enhancement outcomes were also undertaken at the completion of the second trial phase.

**1. Community managed water bodies as a focus for development**

- Extensive areas in 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 rain-fed 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 sequentially 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 management was changed in favour of central control via the Department of Agrarian Services charged with agricultural extension. These attempts to nationalise such a widely dispersed micro-resource proved ineffectual with state institutions having neither the resources nor capacity required to take on such an ambitious task. 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:
  - *The production systems:* The appropriate time and spatial scales at which aquatic and related agricultural production systems work
  - *Access characteristics:* The *de facto* nature of access arrangements by different stakeholder groups to common property resources including seasonal water bodies.

## 2. The nature of seasonal tanks in watersheds of the Dry Zone

- The potential value of seasonal water bodies for a variety of uses reflects 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.
- Perceptions of seasonality are affected by their major use, irrigation, rather than for fish production.
- 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 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 to pasture and increasing farm mechanisation.

- *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.

### **3. Demand for inland fish**

Freshwater fish, especially tilapias, are important in the diets of poor people in the Dry Zone. The 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.
- *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 rain-fed 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.

In 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 rain-fed areas. The costs to entering trading are low, the fish sold (without ice) are very fresh and benefits well distributed. Fish from seasonal tanks do not tend to enter this marketing chain, mainly for the reasons given above, although they are an important source of snakehead and a variety of other, usually small, indigenous fish.

### **4. The nature of seasonal tanks and implications for aquatic production**

- *Seasonality*: 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 uncharted or quantified due to their relative physical inaccessibility; uncharted, mostly small radial tanks represent 47% of 116 tanks mapped in 13 watersheds of 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 less seasonal or perennial.
- *Perceptions of seasonality*: Farmers often characterise seasonality according to their primary water use *i.e.* irrigation. They may classify tanks as being ‘dry’ when sufficient dead storage remains for bathing, use by livestock and to allow fish stocks to survive.
- *Supplementary irrigation*: the main purpose of the tanks is for irrigation supplementary to rainfall. A variety of factors 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.
- *Cascades*: In addition to their seasonality, the filling and over-spilling of the tanks is a critical feature of these ‘cascading’ tanks systems. The frequency and duration of spill events links successive tanks in a cascade sequence and determines the potential for fish migration/ natural recruitment in upper seasonal tanks following years in which they have completely dried out.
- *Frequency of spill events*: Most spill events take place after the main NW monsoon. In average and below average rainfall years, spill events are less common and this has been related to extensive cascade impoundment and increasing frequency of drought. Smaller tanks tend to spill more frequently but for a shorter period and prior to the onset of spill events in larger tanks.
- *Aquatic weed encroachment*: Smaller shallower tanks are likely to have high levels of encroachment by rooted aquatic macrophytes encroachment for much of the year with significant impacts for fisheries management.
- *Fish production*:
  - *Nutrient availability*: Seasonal tanks are potentially highly productive. Watersheds act as sinks for nutrients and their shallow nature and frequent exposure of sediments ensures 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 and densities of predators low.
  - *Fish stock recruitment*: Fish yields show highly erratic historic trends however. If tanks completely dry out and fish stocks disappear, productivity is reduced until repopulation can occur, normally through migration upstream at spill events. Thus a combination of climatic factors, the nature of water availability (*hydrological endowment*) at the individual tank and cascade level, and farmer irrigation responses to these factors affect productivity. The replacement of traditional earthen spillways with more durable concrete

structures also presents an increasingly significant impediment to upstream migration and repopulation of seasonal tanks.

- *Tank Seasonality*: The volume and duration of water storage in seasonal tanks determines whether sufficient fish stocks persist from one rainy season to the next. Potentially carry over of stocks allows both recolonisation of the same tank and, after migration upstream, to other tanks higher in the watershed.

### **Classification of tanks based on natural fishery potential**

| Seasonality class | Description   |
|-------------------|---|
| Highly seasonal   | Completely dry every year with complete loss of fish stocks             |
| Seasonal          | Completely dry more than once every 5 years                             |
| Semi-seasonal     | Completely dry at least once every 5 years                              |
| Perennial         | Has not dried in living memory (other than for rehabilitation purposes) |

## **5. 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. We 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.

### *5.1 Categorisation of social boundaries*

Two principle forms of Dry Zone rural settlement exist, often in close physical proximity; (1) *Purana* villages and (2) irrigation colonies which have resulted from traditional and modern patterns of settlement respectively.

- *Purana villages*: The more traditional settlements typical of rain-fed areas in the dry-zone are known as *Purana* (old or traditional) villages. In inland areas, these are constituted almost entirely of Sinhalese Buddhist populations.
- *Irrigation colonies*: Development of major irrigation systems over recent decades aimed at relieving population pressure in the hill country has resulted in the establishment of ‘irrigation colonies’, often the size of a small town, benefiting from good physical infrastructure. They are typically populated by heterogeneous kinship groups despite some attempts to resettle entire communities. These settlements exist within major irrigation systems and intensified agriculture together with service opportunities mean significant off-farm labour opportunities are available for inhabitants of neighbouring *Purana* villages in rain-fed areas.

- *Tanks and community size:* A typical Purana community 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 tank.
- *Lower and mid-watershed PCs:* The oldest Purana villages tend to be established around the most reliable perennial or larger semi-seasonal (non-system) tanks. 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.
- We coin the term '*Purana Complex*' (PC) to define groups of villages/communities with strong kinship links sharing access to the same resources. Within PC boundaries discrete community groups of uniform ethnicity, religion and caste access the same surrounding radial and axial tanks, as well as other natural resources. Rather than the traditional household or individual tank level we identify the PC as the smallest logical watershed sub-unit for intervention in rain fed areas.
- *Wealth and upper watershed PCs:* 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 typically 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.
- *PC & watershed boundaries:* 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.
- *Size and complexity:* 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.

*Institutions:* The range of formal institutions in *Purana* villages is limited. Externally constituted institutions including farmer's organisations responsible for irrigation decisions tend to be the unrepresentative of the village as a whole and tend to be dominated by better-off households with most land. The most active identified were Death Donation Societies, which are indigenous community welfare groups that manage micro-credit for the often-expensive funeral rituals. These organisations are widespread and represent considerable social capital. They are constitutional and

democratic, include even the poorest households, hold regular, well documented meetings and have clear, sanctionable rules. Membership of community- based institutions infrequently extends across PC boundaries, but when it does it is linked to inter-community leasehold / ownership of paddy lands. Membership of a neighbouring Death Donation society may suggest kinship linkage or poor social cohesion in the PC in question.

### 5.2 Access to tank fisheries:

- *Between communities:*
  - *Marginal upper watershed communities* exhibit greatest reliance on the natural resource base, including fisheries, for subsistence purposes, 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.
  - *Fishing by hook and line*, often in waters heavily encroached by aquatic macrophytes, is the norm 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 and turbidity levels fall (3) as the method brings 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 (which become more efficient as turbidity increases and water storage levels fall during the dry season). Dry-season collective fishing is often a shared social event with members of neighbouring villages. It can either create conflict or increase social cohesion between communities depending on site-specific contexts.
  - External attempts to enhance fisheries can undermine these, often subtle, informal access relationships, especially if marginal groups are ignored or excluded. However, the formalisation of access rights is 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.
- *Within communities*
  - Whereas caste and kinship are the principle characteristics demarcating inter-community access, internal access is conditioned primarily by wealth, gender and age. Traditionally, harvest of fish from seasonal tanks is a collective activity occurring at two main times during the year (1) during spill events as rainfall peaks and (2) just prior to total drying out of tanks. In both cases little or no specialist gear is required and such collective action prevents loss of fish from the community resource.
  - *Age and wealth:* 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. Younger, poorer people 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.

- *Gender:* 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.
- *Collective harvests:* 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.
- *Community hierarchies:* Even when methods which create little conflict with alternative water uses are practiced (such as intermittent fishing with hook and line) conflicts associated with re-distribution of fish yields can still arise. Whilst 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.

## **6. Intervention approaches to benefit the poor**

### *6.1 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 spillways 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. These changes are targeted mainly to the needs of local irrigators despite having impacts on a range of water uses including fish production. Furthermore, both planners and farmers have a poor perception of these impacts / resource flows operating upstream and downstream within the same watershed.
- The recent history of tank rehabilitation and other interventions is that communities view them as a form of immediate and tangible benefit from outside, often as part of complex patron-client relationships with government agencies, rather than being part of a process of change mainly occurring



within the community. Any successful strategy will aim to build more sustainable social capital

## 6.2 Fisheries interventions implications

- *Conventional efforts to promote aquaculture* in seasonal water-bodies have focused on technical innovations such as identifying what kind of fish species 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 may have created or exacerbated conflicts within and between communities.
- *Enhancement based on hatchery seed*
  - *Enhancement* based on stocking hatchery-produced, usually exotic carps (e.g. common carp, bighead and rohu) has demonstrated that high, although often-inconsistent, fish yields are possible in larger tanks. This can be related to their inherent productivity. 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, probably explain this 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. If public sector fish seed production is to be revived through any substantial reinvestment, it would therefore need to be linked to supplying seed for stocking tanks. The private sector is unlikely to become interested given the established opportunities for value-added ornamental fish production.
  - *Local nursing* of hatchery carp fry has been promoted successfully elsewhere 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 but the complexity, and costs of management required, along with the heterogeneity of seasonal tanks mean that it is unlikely to become an approach suitable for widespread promotion.
- *Enhancement based on natural stocks*
- *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. This research has indicated 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.
  - *Tilapias and snakehead*: harvested from perennial tanks within the same watershed as small seed using hand nets by community members net 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 need to be stocked at the same time or slightly later to avoid later 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.
  - *Gourami and small indigenous species*: The exotic snakeskin gourami whilst typically growing to little more than 50-60g breeds and occurs in large numbers under seasonal tank conditions. Although they spoil rapidly, they are highly amenable to hand or 'mud' fishing by young boys with little requirement for other gears. The poorest groups, such as female-headed households with dependent children, subsequently harvest the many smaller individuals that escape collective fishing. Other small indigenous species including; climbing perch, yellow catfish, *Puntius* spp. and *Rasbora* spp. are also consumed in smaller quantities and constitute important prey species supporting snakehead production.
- *Factors reducing potential productivity and value*
  - *Loss of stock*: Once the 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 upward migration of fish occurs from perennial water bodies lower in the watershed.
  - *Late stocking*: In some communities entrepreneurial individuals have stocked tilapias from other tanks that retain water or have even purchased from itinerant traders selling large perennial tank fish. More 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.
  - *Unbalanced predation pressure*: 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.
  - *Single, complete harvest*: 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 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.

- *Introducing new practices*
  - *Early stocking*: The perception of communities 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.
  - *Stocking strategic nodal tanks*: Small axial tanks with the greatest number of hydrological linkages to seasonal tanks further up the watershed would be most cost effective to encourage stocking self-recruiting species on a whole watershed basis.
  - *Frequent and intermittent harvest*: This practice already exists to a greater or more limited extent, usually by poorer more marginal people. Community perceptions regarding the acceptability of the practice are finely to the precise timing and methods adopted.
  
- *Constraints to uptake include*:
  - Poor knowledge of the potential savings of cash used to purchase fish.
  - Expectations that frequent harvesting activities involving tank entry will increase water turbidity and loss of water through the tank bed to the detriment of quality of water for bathing and quantities available for irrigation respectively multiple-use conflicts.
  - Attitudes to certain types of intermittent fishing; the use of worms for hook and line fishing is perceived negatively.
  - Loss in perceived control by community hierarchy; more inclined to promote traditional single harvest when yields could be bulked and sold for income generation and/ or collection 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.

### 6.3 Identifying communities for interventions

The following factors should be considered in identification of communities for intervention

- Identify appropriate PCs rather than single communities around single tanks using geographical and social mapping with key informants
- PCs most appropriate for interventions tend to occur in upper watershed areas where many poorer low caste groups most dependent on natural resources live. They tend to have strong kinship links between individual communities.
- Other indicators are strong Death Donation Societies that have good representation from the poorest households. Checking membership and attendance records is a useful check of the social capital within the PC.
- The communities live close to, ideally within view, of the seasonal tanks. This assists in observation of rules and prevents free-riding.

### 6.4 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 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
- Promotion of hook and line intermittent harvest using non-live lures
- Community meetings in which overall benefits discussed
- Promotion in neighbouring communities and watersheds at the same time so that reduced intercommunity access is compensated by better outputs from local tanks, together with savings in travel time
- Integrated small water user-groups - combining fish enhancements with other multiple-use activities 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.

### 6.5 Implications for tank rehabilitation

The potential negative effects of tank rehabilitation prompt an assessment of rehabilitation approaches. The following are suggestions for maintaining or improving fish production in tanks.

- *Small refuge areas:* Excavation of small refuge areas (15-20m<sup>2</sup>) 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 erosion.
- *Increasing tank capacity through raising height of the bund:* Increasing capacity through deepening tanks by removal of sediment can adversely affect nutrient status and productivity, in addition to its impacts directly of fish stocks through reducing seasonality and spill frequency. Increasing tank capacity through raising

the height of earthen bunds or spillways could increase fish productivity through the inundation of highly productive shallow littoral areas for longer periods of the year

- *Migration-friendly spillway design*: There is a trend to install concrete spillways on progressively smaller tanks replacing traditional earthen spillways. This represents an additional constraint to migration, which could be overcome by simple design modifications.