The integration of poverty-focussed aquaculture within large-scale irrigation systems: guidelines for planning and implementation

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Preface

This document was prepared on the basis of evidence and experience gathered from a collaborative research project involving the University of Newcastle upon Tyne (UK), University of Stirling (UK), Tamil Nadu Agricultural University (India) and University of Peradeniya (Sri Lanka).

The authors wish to thank all members of the research team who contributed to the project and in particular:

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Introduction

1.1 Background

It is generally acknowledged that since the 1960s technological advances in agriculture, collectively known as the “Green Revolution”, have provided the means for the developing world to feed its growing population. The dominant role of irrigation development in promoting food security is also recognised, since irrigated agriculture globally produces 40% of food and agricultural commodities and in Asia the dependence is most critical, being some 60% of total production. The corollary of this dependence on irrigated agriculture is that virtually everywhere that irrigation is practised it is the largest consumer of water. Currently 70% of all water extracted from rivers and underground aquifers is used for irrigation, but in Asia the dominance is still greater, being 90% of total abstraction.

During the 1990s there was a dramatic shift in priorities for water resource allocation and development. Water scarcity has become a prominent issue with the result that irrigation is seen as both a profligate and a low-value user of water resources. Notwithstanding concern over future food security, there is great pressure to use water more effectively and often this involves reallocation of resources away from irrigation and in favour of municipal, industrial and environmental uses. It is important that any decision to reallocate resources in this way, should be based on a complete understanding of the multiple use of water within irrigation systems. This is leading to new perceptions of the need for proper understanding and economic evaluation of non-irrigation uses and to greater recognition of the linkages between water management activities and aquatic ecosystems.

It is a common perception that irrigation systems supply water only to field crops, but the true picture is more complicated. Even within the agricultural sector, irrigation systems supply water not only for the main fields, but also for home gardens cultivation and for livestock. Other productive uses may include fishing, harvesting of aquatic plants and animals and a variety of other enterprises such as brick-making. Important environmental functions may include water supply to trees and other permanent vegetation, which provide an amenity to the local population and support biodiversity in plants, birds and other animals. Other non-productive uses may include laundry, bathing
and domestic supply. Important implications for water management and policy arising from recognition of these multiple uses include considerations of: the valuation of water in irrigation systems, how systems are managed to maximise productivity and environmental sustainability and equity considerations amongst multiple stakeholders.

The focus here is on fish production within irrigation systems and, in particular, opportunities for poor people to derive a livelihood benefit from this activity. It is evident that the extensive development of water resources for irrigation has sometimes had a profound negative impact on river ecosystems, which is reflected in a dramatic loss of bio-diversity. Where this has resulted in loss of important subsistence fisheries, the impact of this change has generally been felt disproportionately by poor people. The opportunity may exist within the newly created irrigation systems to mitigate this negative impact by promoting complementary development of fish production, but this has generally been overlooked. There has been little consideration given to the replacement of lost fishery potential through systematic development of aquaculture potential. Surprisingly little research evidence exists linking fish production to irrigation, either in terms of the impact on natural fisheries or the potential created for new managed fisheries. Furthermore, the linkages between fisheries management institutions and water management institutions are generally weak.

It is in this context that a research project which focuses on the integration of aquaculture within irrigation systems was formulated. This document does not attempt to present a full account of the research, rather it builds upon this field-work together with experience from elsewhere in order to present guidelines for planning and implementation of initiatives aimed at integration of poverty-focussed aquaculture within irrigation systems. Project activities are summarised briefly below, but full details can be found in the Technical Annexes to the Final Technical Report\(^1\).

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\(^1\) Integration of Aquaculture within Irrigation Systems (DFID research project R7123), Final Technical Report, Centre for Land Use & Water Resources Research, University of Newcastle upon Tyne, 2002.
1.2 Research project activities

Interdisciplinary research teams conducted extended fieldwork at case study sites in India and Sri Lanka (see section 1.3) on three key areas of research, as follows:

Socio-economic studies combined quantitative surveys at household level with qualitative studies based on PRA techniques in sample villages to investigate:
- livelihood characteristics, strategies adopted by poor people and the importance of water;
- potential of aquaculture as an alternative or supplementary income generating activity;
- potential for improved water-use efficiency through integration of aquaculture/irrigation.

Engineering studies explored constraints to integrating cage-based aquaculture in irrigation canals and in secondary storage structures (tanks) within the irrigation distribution networks:
- secondary data sources allowed time-series analysis in order to investigate duration and reliability of conditions suitable for aquaculture;
- primary data collection provided a basis for assessment of the impact of cages on flow in the canal and of cage anchorage and access issues;
- analyses of canal operating procedures in response to rainfall and of management of tank storage in combination with in-depth studies of water management provided a basis for considering whether multiple-use management is compatible with a desire for efficiency.

Aquaculture studies began with in-depth consultations with primary stakeholders, which identified cage-based aquaculture as an appropriate technology. This led to
- trials on cages at selected sites both in flowing canals and in tanks;
- investigations of the nature of the market for fish, particularly among rural consumers;
- investigations of attitudes of target beneficiaries to the proposed technology and requirements for its successful adoption.
1.3 Case study sites

On the basis of initial consultations with a range of stakeholders one irrigation system was selected in each target country as a representative case study site. Both lie within semi-arid environmental zones and both experience a tropical monsoon climate. Both experience water scarcity. Both are public irrigation schemes, which are managed by large bureaucratic organisations. At the time of the research, both were attempting to introduce institutional reform aimed at devolving some management responsibilities to water users.

Lower Bhavani Project

The Lower Bhavani Project (LBP) is in Tamil Nadu state in the South of India. Its water source is the Bhavani River, which rises in the Nilgiri Hills and is a tributary of the Cauvery River. It was selected as a representative valley-side system, comprising a 200km contour canal serving a command area of 78,500ha. Storage is provided at the head of the system in Bhavanisagar dam, but there is no secondary storage. The system is about 45 years old.

LBP main canal operates for two seasons each year, in only one of which it is said to deliver a “continuous” supply. Design capacity at the head of the system is 65m$^3$/s, where the canal bed-width is 32m and full supply depth is around 3m. In the tail reach, canal dimensions reduce to 4.5m width and 1m depth. The canal is unlined for most of its length with generally rocky bed and carries a low sediment load.

Mahaweli System H

System H was the first scheme developed under the Mahaweli Development Programme and has been operational since 1978. It is situated in the so-called “dry zone” in the North Central province of Sri Lanka. The command area of 24,500ha is served by three main canals, drawing water from Kalawewa reservoir, which is partly supported by transfers from the Mahaweli system. During the “Maha” season water is issued to the full command area and rice is the dominant crop. During “Yala” season water is rationed and only about 50% of the command area is cultivated, mainly with non-rice crops.
The feature of System H, which is of particular interest is the presence of over 100 secondary storage structures, known as “tanks” distributed throughout the command area. These structures existed prior to the development of the canal system, but were rehabilitated and linked into it. In some cases, water is delivered to the tank via a direct connection to the new canal system, while others receive irrigation return flow.

System H was developed as a settlement scheme involving transfer of settlers from other parts of Sri Lanka, which were considered to be over-populated. It now faces a problem in providing livelihood opportunities for second-generation settlers without fragmenting the already small land holdings, which were allocated to the original settlers.
2. **Scope of guidelines**

2.1 **Rural aquaculture and the poverty focus**

Rural aquaculture is a term which defies simple definition (Edwards, Little & Demaine, 2002). The use of the term represents recognition of the fact that poor people have been bypassed by mainstream aquaculture development. The aim therefore is to improve the livelihoods of the rural poor through farming of aquatic species using extensive to semi-intensive technologies (see Box 1). Rural aquaculture systems include both land-based systems, typically integrated with agricultural practices (e.g. farming fish in deep-water paddy fields) and water-based systems, involving "stocking fish directly in enclosures or attaching them to substrates in water bodies such as rivers, lakes, reservoirs or bays" (Edwards, 2000).

**Box 1: Comparison of aquaculture systems**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Extensive</th>
<th>Semi-intensive</th>
<th>Intensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking density</td>
<td>Low (&lt;5000)</td>
<td>Moderate (up to 50,000)</td>
<td>High (up to 500,000)</td>
</tr>
<tr>
<td>Feed</td>
<td>Natural food only</td>
<td>Supplementary low-cost (bran, manure etc)</td>
<td>Commercial (20-25% protein)</td>
</tr>
<tr>
<td>Management</td>
<td>Stocking, harvesting</td>
<td>Stocking, feeding, harvesting</td>
<td>Stocking, feeding, water control, stock manipulation harvesting</td>
</tr>
<tr>
<td>Investment cost</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Operating inputs</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Yield range (kg/ha/year)</td>
<td>Low (&lt;1000)</td>
<td>Moderate (1000 - 15000)</td>
<td>High (&gt; 15,000)</td>
</tr>
</tbody>
</table>

A poverty-focused approach seeks to reduce the use of cash inputs, especially for the purchase of off-farm feeds that are most difficult for the poor to sustain and to substitute the use of household labour, land and other resources. Low cost does not necessarily mean ‘extensive’ as defined above, as land and water may be expensive resources. Often richer people manage and benefit most from such extensive systems. Ownership of the water resources on which the aquaculture system is based is not a pre-requisite. *Access* to the water body is crucial to allow groups of poor people such as the landless
and women (who usually lack assets such as land and ponds), to get involved in aquaculture regardless of their social or economic status. Emphasis is normally placed on open access or common property water resources to support poverty-focused aquaculture development. However the access afforded to, and provided to, poor people and their stake in management of the natural resource must be both secure and assured if sustainable, and profitable, livelihood-enhancing, poverty-focused development is to take place.

Indirect implications are the participation of poor people in determining suitable aquaculture systems adapted to their needs, along with their long-term environmental sustainability. Finally, to reach its target group and to be a suitable entry point for poverty alleviation, outcomes and benefits from aquaculture have to compare favourably with other, and possibly less risky, locally available income generating activities for the resource poor. Attention must be paid to factors such as availability of water and local materials from which to manufacture physical capital such as fish cages (cheap and strong to withstand high velocity water flows). From a socio-economic perspective, availability of potential feed stuffs such as fodder, labour (and its gender differentiation), fish preferences and near market proximity have also to be considered to ensure both constant returns to scale/size and prevent market exploitation of small-scale producers along an uncompetitive, fish supply chain.
2.2 Technical options for poverty-focused aquaculture

Most irrigation systems probably sustain capture fisheries to some extent, although the practice is generally opportunistic. Usually, fish stocks are dependent upon fish entering the canal system from the source. Some species may form self-sustaining populations, but this is limited to those systems having favourable environmental conditions (eg. storage structures as in System H). A degree of management of fish stocks will be required to maintain a more productive sustainable fishery. Such management may involve restocking and introduction of new species, but there is little recorded experience of such measures being adopted in canal systems, except where they have been primarily aimed at weed control through stocking of grass carp.

Aquaculture offers greater control over production and access than is the case with capture fishery and even low-cost, semi-intensive systems can produce 1500-2000kg/ha/year, which compares favourably with estimates for production from capture fisheries in canals. Suitable fish species are indicated in Table 1. Aquaculture systems geared towards reducing poverty include the following characteristics;

- High stocking densities used to reduce risks from predation and theft.
- Based on herbivorous/omnivorous fish species that will
  - tolerate transportation and handling well
  - survive and grow well in small, seasonal production units
  - consume natural feeds and locally available supplementary feeds
- Based on free or very cheap inputs easily obtained without loss of social or natural capital
  - Includes use of sewage for fertilising fish ponds
  - Removal and reuse of livestock wastes in fish culture
- Multiple harvest of small fish reducing risks and improving cash flows
- Dependence on fish seed delivery by poor traders; reduces knowledge requirement by producer to obtain seed and links with broader knowledge base
- Fish can be marketed locally either directly or through poor intermediaries
Cage culture

Cage-based aquaculture has been practised in parts of China and South-East Asia for many generations. Now more than 70 species are cultured in cages of various shapes and sizes in both flowing and still waters. Cages can be made cheaply using widely available materials, such as bamboo (for frame) and plastic containers (for floats), but availability of suitable netting can be a constraint (Beveridge, 1996; Haylor, 1993). Cages may have benefits for poverty-focused aquaculture because they can be small and easily managed with respect to:

1. where they are sited; in principle allows their movement between and within water bodies in response to seasonality of water availability and/or social access/conditions
2. capital and operating costs; small cages with high stocking densities of fish are more efficient and productive than larger cages at lower stocking densities. This reduces the entry cost of aquaculture and allows risk to be spread.
3. removing the need for specialist knowledge and expensive harvesting equipment, although this may reduce opportunities for marginalized fishers
4. obtaining seed and feed. May be more manageable with respect to investment by fishers if smaller rather than larger numbers of fish are required.
5. protection against theft. The small size/level of investment may in contrast reduce the incentive for adequate control or prevention of theft and or require a group/community-level initiative with all its costs and problems.

Pen culture

An alternative is to produce fish in larger containment structures known as pens. Like cages, their sides are man-made, but an important difference is that the base is the canal substrate itself. This allows access to benthic organisms, providing an additional food source for the fish. At the same time it makes them less suitable than floating cages for canals with widely fluctuating water levels. Pens may be created by enclosing the full width of the canal, or may be aligned along the bank and occupy only part of the canal width (Beveridge, 1996; Haylor, 1993).
Table 1: Commercially important species of fish in inland cage and pen systems

<table>
<thead>
<tr>
<th>Species</th>
<th>Countries</th>
<th>Climate</th>
<th>Type of feeding</th>
<th>Cage/Pen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainbow trout</td>
<td>Europe, North America, Japan, high altitude tropics</td>
<td>Temperate</td>
<td>Intensive High protein</td>
<td>Floating cage</td>
</tr>
<tr>
<td>Salmon (various spp)</td>
<td>Europe, North America, South America, Japan</td>
<td>Temperate</td>
<td>Intensive High protein</td>
<td>Floating cage</td>
</tr>
<tr>
<td>Chinese carps</td>
<td>Asia, Europe, North America</td>
<td>Temperate - tropical</td>
<td>Mainly semi-intensive, but also extensive (in Asia) and intensive (in Europe, North America)</td>
<td>Cages and pens</td>
</tr>
<tr>
<td>Indian major carps</td>
<td>Asia</td>
<td>Sub-tropical, tropical</td>
<td>Semi-intensive</td>
<td>Mainly cages</td>
</tr>
<tr>
<td>Common carp</td>
<td>Asia, Europe, North America, South America</td>
<td>Temperate - tropical</td>
<td>Mainly semi-intensive</td>
<td>Mainly cages</td>
</tr>
<tr>
<td>Tilpias</td>
<td>Asia, Africa, North America, South America</td>
<td>Sub-tropical, tropical</td>
<td>Mainly semi-intensive</td>
<td>Mainly cages</td>
</tr>
<tr>
<td>Catfishes</td>
<td>S.E. Asia, Africa</td>
<td>Tropical</td>
<td>Semi-intensive</td>
<td>Floating cage</td>
</tr>
<tr>
<td>Snakeheads</td>
<td>S.E. Asia</td>
<td>Tropical</td>
<td>Semi-intensive</td>
<td>Floating cage</td>
</tr>
<tr>
<td>Panganius spp.</td>
<td>S.E. Asia</td>
<td>Tropical</td>
<td>Semi-intensive</td>
<td>Floating cage</td>
</tr>
<tr>
<td>Milkfish</td>
<td>S.E. Asia</td>
<td>Tropical</td>
<td>Semi-intensive</td>
<td>Pens</td>
</tr>
</tbody>
</table>

Source: Beveridge, 1984
2.3 Characteristics of Large-Scale Irrigation Systems

These guidelines are concerned with large-scale irrigation systems, which can be defined in terms of their physical characteristics and also of their organisational characteristics. Size of the command area alone is not the distinguishing feature, since a 1000ha scheme may be classified as a “major” or “large-scale” scheme in one country, but be regarded as “minor” or “small-scale” in another. A more useful definition of the scope of these guidelines is that they concern:

- formal hierarchies of open channels for delivery of irrigation water and for removal of drainage water;
- formal organisational structures with a legally constituted management institution responsible for control of water allocation and delivery.

All formal large-scale irrigation systems comprise four functional sub-systems: water source, water delivery, water use and water disposal. Figure 1 is a representation of these sub-systems and their water-flow linkages. Potential niches for integrating aquaculture are highlighted in the diagram and discussed further in Section 5 of these guidelines. From this perspective, the key features are:

- the hierarchy of primary, secondary, and tertiary canals and drains within the water delivery and water disposal sub-systems;
- the water storage structures distributed at various levels in all sub-systems.

A minority of irrigation systems include pipelines instead of open channels for part of their water delivery and/or water use sub-systems, in which case these guidelines apply only to their associated open channel systems.

As the size of command area may vary, so will the capacity and size of the primary and secondary canals. Typically, a primary canal may be 5-50m bed-width and 1-5m depth. In most circumstances, it will be designed to operate more-or-less continuously throughout the irrigation season. Design velocity depends on: the nature of the bed material, whether it is lined or unlined, and whether it carries clear or sediment-laden water. Secondary and tertiary canals deliver water to progressively smaller sections of the command area and have accordingly smaller bed-widths and depths. They are less likely to operate continuously.
Water storage structures provide operational flexibility in that they buffer differences between supply and demand. Distributed storage within the water delivery system is not always present; where it exists it may be provided as a buffer between primary and secondary canals or between secondary and tertiary canals. Storage may also exist within the water-use sub-system as on-farm storage; either as farm ponds or within paddy basins. Important differences between storage structures are the duration and depth of storage, and the frequency and rate of variation.
Figure 1: Principal components of an irrigation system and possible niches for aquaculture

- **Groundwater Recharge**
  - Water Source Sub-System
    - Storage dam
    - Run-of-river diversion
    - Open wells

- **Drainage Recovery**
  - Water Delivery Sub-System
    - Primary canals
    - Secondary canals
    - Distributed storage

  - Water Use Sub-System
    - Tertiary canals
    - Field channels
    - Buried pipes
    - Farm ponds
    - Irrigated fields

  - Water Disposal Sub-System
    - Field drains (ditches/pipes)
    - Collector drains
    - Primary drains
    - Evaporation ponds

Additional inflows (possible sediment and/or contaminant load)

Management losses

Return Flow (possible contaminant load)

Drainage
3. Using the guidelines

These guidelines are intended for use in poverty-oriented actions, that is to say, where the poor are explicitly targeted. We are therefore seeking to introduce and promote appropriate technologies for aquaculture within irrigation systems where these are likely to provide livelihoods benefits to poor people without unacceptable impacts on other water users. A general framework for the assessment is shown in Figure 2 and detailed guidelines related to each of these areas of concern are provided in the sections that follow.

The aim of the intervention is assumed to be to improve the livelihoods of the rural poor and to promote food security through improved food supply, employment and income. In the past poor people have been largely by-passed in aquaculture development and there specific needs require careful consideration. It is by no means certain that the introduction of small-scale aquaculture technologies will contribute to the alleviation of poverty. There may be better ways for poor people to use their limited resources. A key question is:

- Is there potential for aquaculture activities to offer livelihoods benefits to poor people?

Having established that there may be potential demand amongst the target group, the next consideration is whether suitable mechanisms exist to introduce appropriate technologies to them. Within the wider context of agricultural development, there is frequent criticism of the traditional transfer of technology based on training and demonstrations. The alternative farmer-first approach attempts to ensure the relevance of the technology by providing options and ideas and developing capacity to evaluate them and make informed decisions. A key question is:

- Do appropriate technologies exist and can they be made available to poor people?

The next requirement is to remove technical and institutional obstacles that may affect the successful adoption of appropriate technologies by the target group. This requires consideration of opportunities and constraints within the irrigation system. The aim is to identify favourable sites (niches) where the environment is suitable for aquaculture and its introduction will not have any adverse impact on the integrity of the irrigation system or on other water users.
The key question is:

- Do suitable niches exist within the irrigation system where they can be introduced?
Figure 2: Framework for assessing opportunities and constraints

- Assess potential from livelihoods perspective
- Establish demand exists amongst potential clients
  - Consider technology options available for integrated aquaculture
    - Identify suitable niches within the irrigation system
      - Evaluate supply duration constraint
      - Evaluate supply continuity constraint
      - Evaluate flow velocity constraint
      - Evaluate flow depth constraint
      - Evaluate quality and turbidity constraints
    - Evaluate supply duration constraint
    - Evaluate supply continuity constraint
    - Evaluate flow velocity constraint
    - Evaluate flow depth constraint
    - Evaluate quality and turbidity constraints
  - Assess requirements for re-engineering scheme to alleviate constraints
    - Identify actions required to alleviate non-technical constraints
    - Assess requirements for revising O & M procedures to alleviate constraints
      - Identify actions required to extend knowledge of aquaculture
    - Assess requirements for revising O & M procedures to alleviate constraints
  - Reassess livelihoods and economic impacts
    - Prepare plan for technically feasible programme
      - Consult further with potential participants
    - Review requirements for legal and institutional change
      - Consult with other water users
4. Policy Guidelines for Poverty-Focused Aquaculture in Irrigation Systems

4.1 Overview

Research and livelihoods analysis in both India and Sri Lanka shows that there is some potential for aquaculture to strengthen household livelihoods if water management constraints can be overcome. However, there are still many unresolved technical, institutional and economic challenges to be met before we can safely and confidently integrate poverty-focused fish production into large-scale, engineer-managed irrigation systems. Our research shows that introducing poverty-focused aquaculture within these irrigation systems is currently difficult and offers limited livelihood opportunities to a few households with spare labour and possibly women. As it stands, cage aquaculture for vulnerable poor people is a marginal livelihoods activity, not a best-bet option and a somewhat risky new venture.

In the villages studied, rural unemployment is not widespread; there are some livelihoods activities available to all groups and, as a consequence, labour use in aquaculture does not have zero opportunity cost. If it is to be widely adopted as a livelihoods-enhancing activity, aquaculture must be competitive with other income earning activities in terms of its economic returns to labour, capital and water inputs. We have tested cage aquaculture options for poor people in both Tamil Nadu, India and in Mahaweli System H, Sri Lanka and, as yet, our results suggest that it has limited potential as a livelihoods-enhancing technology.

Livelihoods research in the villages established both the degree and gradients of poverty in irrigation systems. In India weaker asset portfolios were encountered at the tail of the irrigation system; wealth and land ownership shape household characteristics but the poor were other important users of canal water often for non-productive and non-consumptive purposes such as bathing, washing and even drinking. In both countries, diversified sources of incomes were generally available to households and access of poor people to the necessary capitals for aquaculture is essential if they are to benefit from any interventions. Distorted asset pentagons showed both financial capital and human capital as important constraints to adoption in poor households. Widespread access to natural capital (i.e. water) is often constrained by institutional rules and procedures.
Weak social capital and community cohesion was the norm in water-deprived and poorer villages and could hinder co-operative initiatives of group-managed aquaculture systems. However, the main challenge for successful promotion of aquaculture in irrigation system lies in establishing that, and ensuring that, low opportunity-cost labour and water coincide within villages in the irrigation systems. Aquaculture technology targeted to the poor must enable them to access a suitable water supply, cages, seed/fingerlings, knowledge and fish handling skills, credit and competitive markets. Proximity to suitable water sources particularly for women is often a constraining influence and in Sri Lanka, women were dependent on men for key tasks in fish culture. Access to and ownership of boats is also often a constraint.

Key policy questions are:-

• How should poverty-focused aquaculture interventions best be made?

• How to manage water-use conflicts, if and when they occur?

• How to establish the trade offs (if any) involved in water, labour and capital use for competing livelihood activities in rural villages?

• How to optimise water use across the whole system?

The integration of poverty-focused aquaculture within engineer-managed irrigation systems should be viewed in the context of multipurpose water resource management. For aquaculture to succeed, it must be accepted that water users other than irrigators also have property rights to water. Access to an assured supply of water in the right quantities and qualities is a key requirement if successful, poverty-focused aquaculture adoption is to take place. It may be necessary to legally recognise, maintain and enforce the water property rights of non-irrigating users. Multiple interests must be operationalised and wider stakeholder representation considered in day-to-day water management and longer term investment policies. A poverty focus does not necessarily
imply maximisation of irrigated agricultural production and wider efficiency and equity parameters must be embraced in performance assessment procedures.

Policy guidance and implementation of policy has implications at both micro (household and livelihoods) and macro (government objectives and national development) levels. Difficult trade-offs and choices related to interventions at the grass roots level and at the national level are likely to arise (Box 2).

**Box 2: Some Possible Policy Trade-Offs**

- Dry season water supply / livelihoods improvements. **versus** Groundwater depletion (environmental damage).

- Dryland crops for subsistence, adapted to water shortages. **versus** Irrigated cash and food crops for the market, exports and national income.

- Adoption of aquaculture by richer households and targeting aquaculture to areas where support networks exist, i.e. promoting 'commercial'-scale aquaculture **versus** Narrowing the gap between rich and poor, creating opportunities for the poorest of the poor, i.e. sustaining the "poverty focus" of development.

- Provision of assistance (subsidies). **versus** Market incentives, entrepreneurship.

- Fish production for local, rural markets and improved nutrition. **versus** Value-adding activities and higher fish prices for urban dwellers.
4.2 Policy Guidelines

It is recommended that policy guidelines be formulated according to the outcome of research findings prior to the integration and promotion of aquaculture technologies in specific irrigation systems to avoid poorly targeted, top-down development.

I - Assessment of Potential from a Livelihoods Perspective.

1. Establish that a market demand exists for fish \( \Rightarrow \) choice of fish species.
2. Determine water and labour availability \( \Rightarrow \) target zones and seasons.
3. Establish the extent of poverty, capital availability and target groups \( \Rightarrow \) target assistance (e.g. credit, knowledge etc) to relevant groups.
4. Carry out Livelihoods Analysis to assess livelihood activities and outcomes \( \Rightarrow \) role of aquaculture: complementary or alternative activity?
5. Assess competitiveness of aquaculture vis-à-vis alternative livelihood activities \( \Rightarrow \) Determine optimal resource allocation,
7. Determine constraints to adoption \( \Rightarrow \) suitably designed aquaculture systems.

II - Policy Formulation.

1. Assess and determine policy instruments to facilitate access of the poor to aquaculture technology. Adoption studies – credit, knowledge and skills, market access.
2. Implement policy to promote sustainable aquaculture.

III - Monitoring: improved livelihood outcomes

1. Monitor uptake of activity, difficulties faced in adjusting policy instruments (for example access to credit, repayment capacities, indebtedness, extension).
2. Investigate if direct benefits from aquaculture (e.g. income, diet) are translated into widening of households asset pentagons, bearing in mind intra-household issues and gender.
3. Monitor changes and poverty impact at household and community levels. Can households overcome vulnerability better? Have conflicts increased in the community? Who are the beneficiaries of irrigation water (has it changed with aquaculture)?

4. Environmental impacts – water quality and quantity monitoring; pollution and sustainability.
5. Engineering guidelines on integrating poverty-focused aquaculture within large-scale irrigation systems

5.1 Overview

It is sometimes reported that irrigation systems provide only a narrow range of habitats with much less diversity than natural rivers (Redding & Midlen, 1991) and sometimes that they provide a wide range of habitats (Fernando & Halwart, 2000). Who is correct? In-depth work in India and Sri Lanka within the scope of the research project\(^2\) was focussed in relatively few sites, but the situation can perhaps best be understood by considering the general case of the four component sub-systems previously defined in Section 2.3. We can then identify the possible niche opportunities for aquaculture that may exist in each sub-system as summarised in Table 2.

Table 2: Niche opportunities for aquaculture in irrigation sub-systems

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>Niche</th>
<th>Aquaculture Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water source</td>
<td>Storage dam</td>
<td>Floating cages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stocked fishery</td>
</tr>
<tr>
<td></td>
<td>Open wells</td>
<td>Stocking</td>
</tr>
<tr>
<td>Water delivery</td>
<td>Primary canals</td>
<td>Pens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cages</td>
</tr>
<tr>
<td></td>
<td>Secondary storage</td>
<td>Floating cages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stocked fishery</td>
</tr>
<tr>
<td>Water Use</td>
<td>Farm ponds</td>
<td>Stocking</td>
</tr>
<tr>
<td></td>
<td>Irrigated fields</td>
<td>Integrated rice/fish</td>
</tr>
<tr>
<td>Water disposal</td>
<td>Primary drains</td>
<td>Pens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cages</td>
</tr>
<tr>
<td></td>
<td>Evaporation ponds</td>
<td>Floating cages</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stocked fishery</td>
</tr>
</tbody>
</table>

---

It is clear that the range of niches that may be available for aquaculture therefore depends on the nature of the irrigation system and opportunities within each sub-system should be evaluated systematically. In general, there will be greatest diversity within rice systems of tropical lowlands, but some niches can probably be identified in all irrigation systems. Conditions prevailing in the different niches must be considered carefully, since they can be expected to lead to different constraints. A checklist for site selection is presented in Box 3. The different constraints are examined in the sections following. Key differences are:

- Stored water (ponds & reservoirs) vs flowing water (canals & drains)
- Upstream conditions (good quality) vs downstream conditions (degraded quality)
- Individual control (private ownership) vs shared control (open access)

In parts of China and SE Asia “integrated aquaculture” within the water-use sub-system has existed for generations and its introduction into other countries has been received considerable attention in recent years. Similarly, the potential and constraints for harvesting and culturing fish within reservoirs of the water-source sub-system are relatively well documented. However, opportunities and constraints within the extensive engineered components of the water delivery sub-system and water disposal sub-system have been largely neglected. These guidelines, therefore focus primarily on the water delivery sub-system.

Consultations with authorities responsible for planning, design, operation and maintenance of the sites selected as representative case studies for the research project have highlighted certain issues that are considered to be of general concern to engineers and managers. Key technical questions are:

- Is it possible to design and operate irrigation supply systems to satisfy needs of fish production in flowing canals?
- Is it possible to design and operate secondary storage structures to satisfy the needs of fish production?
- Do fish containment structures (ie. pens and cages) represent an unacceptable obstruction that adversely affects performance of the irrigation system?
- Is multiple-use management of irrigation systems (specifically for integrated aquaculture) compatible with a desire for efficiency?
### Box 3: Checklist for site selection

<table>
<thead>
<tr>
<th>Category</th>
<th>Key factors</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality</td>
<td>Temperature, Turbidity, pH, Salinity</td>
<td>Distance from possible inflows (pollution risk) Possibility of inflows from ponds (disease risk)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current velocity</td>
<td>Canals: velocity maybe too high for optimal growth of fish and/or restrict access (see below)</td>
<td>Velocity is lower close to canal banks, on inside of bends and in backwater regions.</td>
</tr>
<tr>
<td></td>
<td>Ponds: lack of current may restrict exchange of oxygen/waste products</td>
<td>Influences design of cages and stocking density</td>
</tr>
<tr>
<td>Water depth</td>
<td>Depth at any site may fluctuate over season</td>
<td>Influences choice of fixed/ floating structures and affects access</td>
</tr>
<tr>
<td>Drifting objects</td>
<td>Floating debris/vegetation</td>
<td>Need for barricade or deflector</td>
</tr>
<tr>
<td>Shelter</td>
<td>Wind/waves</td>
<td>Avoid exposed sites with long wind fetch</td>
</tr>
<tr>
<td>Shade</td>
<td>UV hazard</td>
<td>Shade may be required if water depth is restricted</td>
</tr>
<tr>
<td>Substrate</td>
<td>May vary from rocky to soft mud</td>
<td>Affects bottom-fixed supports and anchorages</td>
</tr>
<tr>
<td>Access</td>
<td>Water depth, Current velocity</td>
<td>Is a boat essential for managing and/or harvesting fish?</td>
</tr>
<tr>
<td>Security</td>
<td>Poachers, Predators</td>
<td>Does close proximity to owner’s home allow adequate protection?</td>
</tr>
<tr>
<td>Other water users</td>
<td>Abstraction points</td>
<td>Domestic users will be concerned about water quality impact</td>
</tr>
<tr>
<td></td>
<td>Access to water</td>
<td>Users entering water for bathing, cattle washing etc represent a risk</td>
</tr>
</tbody>
</table>
5.2 Engineering Guidelines

I Supply duration and reliability

Fish production poses a far greater challenge to system managers than irrigation in that continuity of supply must be guaranteed for the duration of the growing season. Whereas crops will suffer no yield penalty from a discontinuous supply because of buffer storage in the soil, fish will not survive any break in supply. This represents the greatest constraint to integrated aquaculture within canals and drains. The following procedure is recommended:

1. Establish what are the authorised start and end dates for the irrigation season.
2. Ensure that the supply duration (irrigation season) matches the requirement for the aquaculture system being considered. It is likely that a minimum of 100 (preferably 120) days will be required, but a longer duration is desirable.
3. From operations records for past years (10 years minimum) check actual start and end dates, thereby investigate actual durations.
4. Establish what is the authorised supply schedule for each canal under consideration. Reject all canals having rotational supply and consider only those with continuous supply over the full season.
5. From operations records for past years (minimum 10 years) check evidence of no-flow periods. Note that in long canals the record for supply at the head regulator will not reflect conditions along the full length of the canal.
6. Investigate reasons for no-flow spells and consider changes to operating rules, in particular response to heavy rainfall in the command area (see Box 4).

Box 4: Ensuring supply continuity during periods of heavy rainfall

Efficient operation of extensive canal systems under upstream control is notoriously difficult, because:

- Long supply canals respond slowly to operational adjustments (more than 5 days response time at the tail of 200km long LBP canal)
- Rainfall may vary significantly across an extensive command area leading to problems with interpreting available data and in determining appropriate action
- Communications between operations staff may be a constraint and this is likely to be worse during critical periods of heavy rainfall

Reliability of conditions suitable for aquaculture depends on design and operation decisions that influence continuity of supply and/or storage, such as:

- What type of regulator structure (overflow type is preferred)? How closely spaced are regulators? What are their operating rules?
- Is secondary storage provided within the water delivery sub-system? Is it actively managed or does it simply receive drainage return flow? What are the operating rules?
II Flow depth and velocity

Flow depth in irrigation canals is typically in the range 0 to 3 metres, while velocity is usually in the range 0.1 to 1.0 m/s. These factors may be important considerations for:

- Fish survival and growth
- Access for feeding/managing/harvesting fish

The desirable range of velocity depends upon the fish species and size. Good water exchange is essential for oxygen supply and removal of waste metabolites from fish. If velocity is too slow then this may be a problem. On the other hand, excessive velocities reduce fish growth rates and contribute to food losses. A range of 0.1 to 0.6 m/s is usually satisfactory, although the upper end of this range may create problems with anchorage of containment structures. If access depends on wading or swimming then the lower end of the range will be safer.

Note that where flow velocity is too high, it is possible to design the fish containment structure in such a way that velocity inside the structure is restricted. The consequence of this action is that the dynamic loading on anchorages will be increased as will flow resistance. Details of a proposed design procedure are given elsewhere³.

The desirable range of depth depends primarily on the type of fish containment structure. Pens and some cages are designed to sit on the bottom. The effective volume (and therefore stocking density) varies with flow depth and in general fixed structures are not appropriate if water depth varies. This is a particular problem if the structure is situated at the side of the canal and does not utilise the full depth. Depth variation is not important in floating cages, but access becomes difficult if depth exceeds 1.2m and water depth should always exceed cage height.

The following procedure is recommended:

1. Review canal design data to obtain the ranges of velocity and depth for each canal reach. Note that these usually represent design conditions (full supply).

2. Investigate velocity distribution and establish the range of actual conditions; taking into account cross-section variation, influence of bends, influence of slope, backwater effects of structures.
3. From operations records for past years (minimum 10 years) check variability of water levels at monitoring points and establish depth variations along the canal.
4. Identify sites where depth and velocity conditions match requirements for aquaculture system being considered.
5. Determine extent of constraint and need for re-engineering and/or change to operating procedures.

III Water quality

Sites selected for aquaculture must meet the pH, temperature, oxygen and salinity requirements of the fish species to be cultured. Additional water quality considerations include:

- Industrial pollutants
- Pesticides
- Suspended sediment
- Disease organisms

The following procedure is recommended:

1. Levels of pH, temperature, oxygen and salinity can be obtained from routine water quality monitoring. Any localised problems associated with point-source pollution should be identified.

2. Industrial pollutants cannot easily be detected by routine monitoring and should be investigated at source. They may represent a hazard to fish or to people eating them if toxic substances accumulate in the fish.

3. Pesticides also cannot easily be detected by routine monitoring. The problem derives from high levels of pesticide usage in some irrigated farming systems. Wind drift has been known to kill fish 200m down-wind and buffer zones adjacent to aquaculture sites may be necessary. However, the greatest hazard is associated with high levels of contamination in drainage return flows and such sites should be avoided.
4. Disease organisms may represent a hazard if drainage from intensively managed fish ponds enters the water delivery system as drainage return flow. Such sites should be avoided.

5. Sediment load is a concern mainly because of the tendency of any fish containment structure to act as a sediment trap. The structure will reduce flow velocity locally and this may cause sedimentation. Measures for its control will need to be given careful consideration. This is related to the general question: do cages/pens represent a serious obstruction? (See Box 5)

IV Legal and institutional constraints

Culture-based (stocked) fishery in open access water bodies (whether canals or reservoirs) raises widely recognised questions, such as:

- Who owns the fishery?
- Who is entitled to fish?
- Who regulates the fishery?
- How are management costs recovered?

In a cage (or pen) aquaculture system the question of ownership of the fish is quite clear, however there are other issues to be considered. These mainly revolve around rights to use the water and rights of access to the irrigation infrastructure

The following procedure is recommended:

1. Review current regulations that determine rights to use water and rights of access to water-bodies. Consider any necessary amendments that will facilitate use for aquaculture while retaining reasonable control.

2. Consult with all existing and prospective water users in defining rights and responsibilities.

3. Where a water-users’ association (WUA) is being (or has been) established, ensure that interests of fish farmers are properly represented. These people may be landless and will be excluded where membership of the WUA is linked to land-ownership within the irrigation system.
Box 5: Do cages/pens represent a serious obstruction?

The limited documented experience of aquaculture in irrigation systems does include some cases of uncontrolled development interfering with canal performance. Careful consideration must therefore be given to:

- Likely impact on canal conveyance capacity and operational performance;
- Possible interference with maintenance activities.

Any cage or pen introduces additional flow resistance and has a local effect on canal conveyance. The question is: does this represent a serious obstruction or can cages/pens be designed and sited in such a way that they have negligible influence on canal water levels and discharge capacity?

The hydraulic performance of any cage or pen is essentially the same. Water flowing through a mesh panel imposes a drag force on the panel, which results in a reduced velocity on the downstream side of the panel. A design procedure based on the theory of fluid drag is presented elsewhere*. This procedure can be applied to a single cage, or to a system of cages in close proximity on a downstream alignment. It permits estimation of current velocity inside the cage and the drag force imposed on the cage. It should be noted that the theory has been shown to give reasonable predictions for clean cage materials, but an allowance should be made for fouling (i.e. accumulation of algae).

Selection of the cage/pen site can make a considerable difference to the influence on the canal and the recommended general approach is to regulate their installation and monitor their impact. Problems are likely to be more severe in a canal system on minimum slope as the effect of increased flow resistance will be to raise water levels upstream, which may affect performance of off-takes and/or lead to overtopping. For a canal built on a steeper alignment with drop structures at intervals to dissipate excess energy, then opportunity to install cages/pens without affecting performance will be greater. In either case, the increase in hydraulic resistance need not be any more severe than the recurrent problem of weed growth. Any site where this is known to be a particular problem and to affect canal performance should be excluded from consideration for installation of cages and/or pens.

Design of the containment structure can also make a difference in that pens may occupy the full width of the canal or may be aligned along the bank and occupy only part of the width. Cages will normally be small relative to the canal width, but may be sited in mid-stream or close to the bank. Where a cage/pen occupies less than 25% of canal width and is sited close to the bank, the current will be partly deflected around the obstruction and its effect will be relatively small.

V Storage Sites

Any storage site within the irrigation system is likely to represent a potentially more favourable niche when compared to any canal site. Duration and reliability constraints are likely to be greatly reduced, thus making the enterprise less risky for target beneficiaries. At the same time, the impact on hydraulic performance is negligible, thus making the introduction of aquaculture less likely to have create any problems for system managers.

In this context, we are not concerned with any large reservoir that may exist within the water source sub-system. Rather we are interested in niche opportunities within any structures providing relatively short-term storage distributed throughout the water delivery sub-system. These may be:

- Night storage reservoirs
- Secondary storage reservoirs

Work within the research project⁴ was focused on secondary storage reservoirs (known locally as “tanks”), which received water from the canal system as well as rainfall runoff from a local catchment and released supplies to a distinct downstream command area. Their key characteristics were found to be:

- Shallow depth (<3m)
- Frequent and rapid water level fluctuations
- Short retention time (rapid turn-over)

It can be assumed that any secondary storage structure will behave similarly, since its function is to buffer flow variations over a short time-scale. The shallow depth of such reservoirs results in wide variations also in water spread area as water level fluctuates. This introduces constraints on siting of cages/pens.

---

6. Guidelines for small-scale producers and extensionists

6.1 Overview

The approach adopted at the case study sites was to identify and engage with poor people as potential producers whilst understanding the context, particularly relating to demand for aquatic products, the potential impacts on poor people as intermediaries and consumers and the availability of resources to support aquaculture. The guidelines are therefore proposed to be of use to agencies and institutions working to improve multipurpose water resource management and reduce poverty in irrigated areas. The guidelines highlight the potential role of aquaculture within irrigated systems on production and consumption in surrounding rain-fed areas and the necessity for situation analysis to extend to, and include, such areas.

The two types of irrigation systems for which the guidelines are particularly relevant include those in which (1) supply canals and (2) off-farm storage resources (‘tanks’) are the main potential water resources that could support aquaculture. A participatory situation analysis identified that cage-based aquaculture held the most promise in both contexts. Various aspects of cage culture were then piloted at both sites with partner institutions. The current context for the specific sites researched is given below;

<table>
<thead>
<tr>
<th>Context</th>
<th>Lower Bhavani Project (India)</th>
<th>System H (Sri Lanka)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>Little conventional pond production</td>
<td>No conventional pond production</td>
</tr>
<tr>
<td></td>
<td>Most fish produced in large and small tanks</td>
<td>Most fish produced in large and small tanks</td>
</tr>
<tr>
<td></td>
<td>Hatchery seed available¹</td>
<td>Hatchery seed unavailable¹</td>
</tr>
<tr>
<td>Demand/consumption</td>
<td>Low current consumption of aquatic products in irrigation system</td>
<td>High consumption and reliance on locally produced fish</td>
</tr>
<tr>
<td></td>
<td>Potential market among the poor for locally produced, low cost fish</td>
<td>High levels of benefits to poor fishers, traders and consumers in proximal rain-fed areas</td>
</tr>
<tr>
<td></td>
<td>Most hatchery-produced fish exported to urban areas</td>
<td></td>
</tr>
</tbody>
</table>

¹ relative availability of hatchery-produced seed
The process adopted at the two case study sites (Figure 3) involved: situation appraisal (analysis of household, institutional and broader resource levels), engagement with community and/or institutions to identify likely best technical option (see Table 3) followed by their piloting and monitoring. It is recommended that this type of approach be followed before any investment in aquaculture development is made for specific irrigation systems.

The research can be viewed as exploratory as there was no current promotion of aquaculture towards benefiting the poor at either location, and the little institutional capacity in place to support conventional aquaculture was, we believe, misguided. It contrasts strongly with research undertaken within active development projects promoting aquaculture or research into improving established aquaculture. The research also identified the potential risks and benefits to the development of other forms of aquaculture to poor groups and further needs for new knowledge.
Participatory Situation Appraisal

• Changes and Trends
• Seasonality
• Consumer preferences and marketing
• Resource assessment

Community Meetings and Workshops

• Assess current situation and peoples’ needs.
• Identify suitable entry points for research/development.
• Assess resource availability and costs

Review workshops

• Assess people’s attitudes to intervention
• Refine production system to accommodate the users’ needs and resources

Longitudinal Participatory Livelihood Monitoring

• Review progress and appropriateness of the system to the user
• Further refine production system

• Assess attitudes and practice of users and other stakeholders
• Monitor broader community and resource situation
• Evaluate sustainability and identify developmental needs

Figure 3: The process of project intervention and monitoring
Table 3: Technical options (showing possible conflicts and constraints)

<table>
<thead>
<tr>
<th>System Impact</th>
<th>Cages in canals</th>
<th>Pond aquaculture</th>
<th>Hapa rearing of fingerlings</th>
<th>Stocking on-farm reservoirs</th>
<th>Stocking open wells</th>
<th>Stocking seepage zones</th>
<th>Fish / Rice aquaculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflicts.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Environmental impacts</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Market competition</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Access to water resources.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>• Feed resources competition.</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• Labour force competition.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Social conflicts</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Constraints.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Technical knowledge.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Water availability</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Water quality</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Physical characteristics of water body.</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Capital investment cost.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Availability of construction materials.</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>• Availability of feed resource.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>• Availability of seed.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Market acceptability.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Market competition.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: + and - denote conflict/constraint or non-conflict/non-constraint respectively.
Cage culture in irrigation supply canals

The situation appraisal identified two potential foci (1) the fattening of small food-fish for local sale to poor consumers and (2) the production of advanced fingerlings for sale to surrounding rain-fed tank based production. In both cases it proved difficult to develop interest among poor people to become involved in participatory trials and most were managed as researcher managed trials. Both of these technical options are of generic interest where promotion of poverty-focused rural aquaculture is proposed.

The constraints to the viability of poverty focused cage aquaculture in canal systems of Tamil Nadu are summarised below:

<table>
<thead>
<tr>
<th>Technical constraints</th>
<th>Economic constraints</th>
<th>Social constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Short water supply periods truncate time period for fish culture</td>
<td>- High cost of cage materials</td>
<td>- Perception that aquaculture in accessible irrigation systems is a high risk activity</td>
</tr>
<tr>
<td>- High quality cage materials required to withstand high water velocities in the canal environment</td>
<td>- Low market price of fish</td>
<td></td>
</tr>
<tr>
<td>- Sub-optimal feeding efficiency (also economic constraint)</td>
<td>- Uncertain demand for large fingerlings in seasonal tanks</td>
<td></td>
</tr>
<tr>
<td>- Poor survival during fry to fingerling production</td>
<td>- Return to labour of fish culture uncompetitive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Aquaculture may not be complementary to other livelihood options</td>
<td></td>
</tr>
</tbody>
</table>

Key issues for extension agents arising from these constraints include;

- Given an open participatory approach, can poor people be involved in piloting potential aquaculture?
- Given local people’s current diets and incomes, is there likely to be a demand for cultured fresh fish even if of small size?
- Are canal flows of a duration suitable to raise fish to a size in demand locally?
- Are potential cage materials available locally or can their supply be facilitated?
- Are hatchery facilities for conditioning fry to flowing water available?
Cage-fattening of tilapias in tanks

The degree to which conventional aquaculture is uncompetitive, especially in a context where inland fish consumption is high, is unusual in Asia and reflects the productivity of the fishery resource and the unusually open and horizontal marketing channels. Local fish are available from perennial tank-based fisheries at low cost and many poor people benefit as fishers, traders and consumers. Additionally high opportunity costs for feed, land and labour constrain full-cycle pond or cage culture. A seasonal decline in fish catches that reduced incomes and increased vulnerability among fishers and fisher-farmers was identified as an issue. Cage fattening of smaller fish harvested prior to this ‘hungry gap’ was identified as a potential approach with fishers and piloted by a number of them at two sites.

A range of benefits to households practicing cage fattening was identified including the improved control of the marketing of fish and the higher perceived quality of fattened tilapia. Traders purchasing fish also favored fish fattened in cages. There was variability between households in how benefits of cage fattening were perceived and prioritized. As has been reported for back-yard livestock production in developing countries, the technical performance of cage-based fattening - or holding of fish was not considered the most important benefit. Income flows, though not significant enough to support purchase of large assets did support extra expenditure during festivals, for agriculture and day-to-day living costs.

Key issues for extension agents arising from these constraints include:
- Identifying strategies with communities that reduce the risks associated with theft such as producer groups, siting of cages etc.
- Developing strategies that ensure gender cooperation – e.g. if fattening fish is based on wild fish caught by men for stocking in cages managed by women
- Identifying the opportunity costs of labour in the household during periods of low fishing effort/efficiency
- Developing management and marketing strategies that encourage use of high stocking densities in small cages to improve the efficiency of both labour and feed use and capital cost respectively.
• The poor production efficiency can be explained by the sub-optimal stocking densities and feeding regimes used. Low stocking densities of tilapias leads to poor performance, related to feeding and reproductive behaviour, especially in cages.

• Technically, using home made feeds from ingredients obtained locally was practical but the small scale of enterprise meant that economies of scale could not be developed, Moreover the opportunity costs of a major feed ingredient the small trash fish, was readily saleable, fresh or dried, in the village for cash.

• Institutional norms in the area regarding fishing controls were inconsistent, politically motivated and increased uncertainty. The adding of value to ‘undersized’ fish through fattening can stimulate further conflicts as it may be interpreted as unfair or unsustainable resource expropriation.

6.2 Guidelines

Generic guidelines developed from the study:-

• Assessment of current patterns of demand for fish, particularly among the poor is essential. Is there evidence for latent demand through current exploitation by the poor of marginal aquatic resources?

• Poor people may potentially benefit less as producers than as intermediaries and/or consumers.

• Conventional pond aquaculture may not be competitive with other uses of land, water and labour in the irrigation system. These case studies suggest that where irrigation cropping is well developed, especially for high value field crops and opportunities for off-farm labour exist, it is unlikely to be competitive for poor producers.

• Productive fisheries and prevailing low values of small fish will also make conventional aquaculture uncompetitive.

• Although cage frames can normally be fabricated locally, high quality net material is often limiting. Substitution with poorer materials is risky, particularly in moving water. Evidence for local trading in quality materials and the replacement of materials subsidised by projects indicates that cage culture is sustainable.
• Identify the current status of fish trading - both food and seed fish in the target area. Is a hatchery sector present, changing (in decline or ascent), or subsidised?

• Previous attempts to promote aquaculture within irrigation systems or their environs may have resulted in the setting up of unsustainable and non-representative institutions.

• Timely stocking of fish seed produced in irrigation systems into rain-fed community tanks can potentially enhance or undermine poor rural livelihoods, depending on how institutional issues are resolved. Generally they have resulted in increased conflicts and loss of access to poorer groups.

• A household focus for aquaculture promotion within engineer-managed irrigation systems cannot ignore broader community and resource issues. In particular the problem of theft from individual cages demands a level of group institutional or community-level development.
References


