Better-practice approaches for **culture-based fisheries** development in Asia

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Foreword

We are pleased to make this manual on better management approaches for culture based fisheries widely available. It is the outcome of collaborative research and development efforts that involved farmers, fishers, rural communities around freshwater bodies such as small reservoirs and lakes, development workers, technicians and scientists in several countries including Cambodia, Indonesia, Lao PDR, Sri Lanka and Vietnam. This manual is not a recipe book. It distills and presents practical experiences, local knowledge, empirical results of scientific studies, and relevant theories into a coherent guide.

Why do we need such a manual? Culture based fisheries have been demonstrated as a cost- and resource-effective way of increasing supplies of fish in rural areas. Importantly, in the development context, it is a communal activity. As such, it needs and engenders cooperation and harmony for proper outcomes and sustainability. It does not involve complicated technical activities. Farmer communities with relatively limited experience in fish culture can productively engage, manage and benefit from culture based fisheries. This manual is part of the efforts to encourage governments to adopt and popularise culture based fisheries and to implement the practices effectively and efficiently. It is specifically aimed to provide guidance to development workers and program planners for integrating community based fisheries into rural development plans and programs, and to farmer communities.

The core scientific information for the manual is based on two projects, funded by ACIAR, in Sri Lanka and Vietnam. The relevance of these projects and their success has been amply demonstrated by the fact that the governments of Sri Lanka and Vietnam have adopted the findings to popularise CBF. Others are in the process of doing so.

To initially disseminate the results, as well as to improve this manual, ACIAR requested NACA, in conjunction with Deakin University, to conduct workshops in selected Asian nations to share and discuss the findings from the research projects. An earlier version of this manual was developed for these workshops, which were conducted in Cambodia, Lao PDR and Indonesia.. The manual has been vastly improved by feedback from the workshop participants.

NACA and ACIAR would like to acknowledge the contributions of ACIAR Research Program Manager Barney Smith and the authors for their combined effort in conceiving and planning the dissemination of the research results, developing the manual and organizing the series of country workshops. We appreciate the assistance of the Mekong River Commission for financing the translation of this manual into Lao, and the Department of Livestock and Fisheries, Lao PDR, the Department of Fisheries of Cambodia and the Directorate of Aquaculture, Indonesia for organizing the workshop in Laos, Cambodia and Indonesia, respectively.

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Contents

Preface

Most developing countries in Asia, as well as some in South America (Cuba, Brazil), have recognised culture-based fisheries (CBF) as an effective way of increasing the supply of fish as food in rural areas, at an affordable price. Culture-based fisheries also provide additional income to rural farmers, thereby contributing to poverty alleviation. Culture-based fisheries have added advantages in that, unlike the more conventional aquaculture practices, they are less resource intensive and need less technical skills at the farmer level. As such, culture-based fisheries are an attractive strategy for investment and development for most governments. These fisheries are also an effective secondary user of water resources in small impoundments in rural areas.

Recognising the importance of culture-based fisheries, the Australian Centre for International Agricultural Research (ACIAR) funded projects in Sri Lanka (FIS/2001/30) and Vietnam (FIS/2001/013). These projects are nearing completion. Both projects have been successful in bringing about legislative changes in the respective countries which will stimulate growth in this activity. These projects have also been responsible, directly and/or indirectly, for the recognition and incorporation of culture-based fisheries in the fisheries development plans of some nations. The findings of these two projects have enabled a 'better-practice' approach for culture-based fisheries to be developed.

It is now opportune to disseminate some of these findings as a manual to the grass root stakeholders in other Asian countries, most of which have recognised culture-based fisheries as a development strategy. In order to achieve this objective, ACIAR provided funding to conduct a series of workshops to be held in Cambodia, Indonesia and Lao People's Democratic Republic (PDR) where culture-based fisheries have been recognised as important. By sharing experiences from successful projects in Sri Lanka and Vietnam, it is expected that these countries will be able to develop their own culture-based fishery practices more effectively, thereby ensuring sustainability.

This manual is the final compilation of the experiences in Sri Lanka and Vietnam, together with the discussions that occurred at the three workshops held in the three Asian countries in October 2005. The manual is divided into two parts:

- Part 1 provides general information on what is called 'better-practice approaches' to culture-based fisheries; and
- Part 2 provides experiences from Sri Lanka and Vietnam and includes a marketing study.

The manual is aimed at a variety of readers, including farmers, extension workers and policy makers.

This manual, titled Better-practice approaches for development and management of culture-based fisheries in Asia, is primarily aimed at all member countries of the Network of Aquaculture Centres in Asia-Pacific (NACA). It is available in print form and through the NACA web site, thereby contributing to the popularisation and development of this important fish production practice in rural Asia.

Thuy T. T. Nguyen
Project Leader

Acknowledgments

The NACA is grateful to ACIAR for funding this project, and to Barney Smith, Manager of the Fisheries Program, in particular for his cooperation throughout the implementation of this project. The inputs from Cambodia, Indonesia and Lao PDR in making the local workshops a success are also gratefully acknowledged. We are also grateful to the organisers* of the workshops in their respective countries.

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Objectives of this manual and target audience

The primary objective of this manual is to provide guidelines for attaining better-practices in culture-based fisheries, an emerging practice in rural areas in the Asian region. It deals will the principles of culture-based fishery practices, primarily based on relatively long-term experiences in Sri Lanka and Vietnam. It is not only targeted at researchers *per se*, but also at stakeholders at the grass root levels, as well as planners and policy developers, particularly those of Asian nations embarking on culture-based fisheries as a strategy to enhance fish food production in rural areas. As such, the manual does not deal with the dynamics and interactions of stocked populations. It deals with the gross factors that are applicable to improving fish yields and therefore revenue; and sustaining culture-based fisheries as a development activity in the long-term. The manual addresses the constraints to culture-based fisheries development in the region, and provides guidelines on ways and means of overcoming such constraints.

PART ONE

CULTURE-BASED FISHERIES DEVELOPMENT AND MANAGEMENT

Why, What and Where?

Why culture-based fisheries?

Fish is a healthy and often a traditional food resource of inland rural areas in Asia. However providing it to a growing population is becoming an increasing challenge for most developing nations. So, strategies that are less resource intensive, and relatively easy to transfer and adapt technically, have to be developed for rural populations. One such strategy is to develop culture-based fisheries, which have several advantages over most other conventional forms of aquaculture:

- Less resource intensive;
- Utilise existing water resources (as a secondary user);
- Technically far less complicated than conventional aquaculture (pond culture, cage culture etc.) so relatively easy to transfer to farming communities;
- A communal activity with the potential to generate synergies within and between communities; and
- Attractive to governments and development agencies as a sustainable strategy that will contribute to enhancing fish food supplies at an affordable price to rural communities, provide an additional avenue of income generation, and generally contribute to poverty alleviation in rural communities.

What are culture-based fisheries?

Culture-based fisheries are essentially a form of extensive aquaculture, or a farming practice conducted in small water bodies (generally less than 100 ha). These water bodies would not be able to support a subsistence fishery due to a lack of adequate natural recruitment of suitable species. Artificial water bodies, not built for fishery/aquaculture purposes (such as pond aquaculture ponds) but often built for irrigation purposes, can be used.

Perennial or non-perennial water bodies selected for a culture-based fishery are stocked with suitable species in pre-determined proportions. The stocked fish live and grow in the water body consuming the naturally produced food organisms in it. The fish are harvested at a suitable time or when the water level recedes. A selected community group, who will have ownership of the stock, prepare the water body for stocking, procure seed stock, and care for the stocked fish, in particular by keeping watch over the stock.

Culture-based fisheries differ from traditional stock enhancement practices in large inland waters in that the group that manages the small water body will have ownership of the stock: in a large water body the fishery will have open access. Thus culture-based fisheries are a form of stock enhancement bordering on aquaculture.

Ownership of the culture-based fishery stock, and the need for some degree of caring for the stock, makes it a form of aquaculture in accordance with the Food and Agriculture Organisation of the United Nations' (FAO) definition of aquaculture.

Culture-based fisheries should also not be confused with capture-based aquaculture, which is the practice of collecting 'seed' material from early life stages to adults from the wild, and on-growing these to marketable sizes using conventional aquaculture techniques. In general, capture-based aquaculture species are carnivorous and relatively expensive, such as eels, bluefin tuna and sea breams. These fish can be on-grown in cages, pens and or in ponds, and the stock is almost always fed intensively.

Culture-based fisheries are developed in common property resources but with fish stock ownership. In almost all such cases, a resource can be utilised for food fish production only by adopting a communal approach. This type of approach also resolves problems in defining ownership that are associated with the size of the resource and other management characteristics as evident from Table 1.

Where are culture-based fisheries developed?

Typically and ideally, culture-based fisheries are developed in small perennial or non-perennial water bodies as shown in Figures 1–4. In Bangladesh, for example, they are developed in oxbow lakes.

In Asia, it is estimated there are approximately 66,710,052 hectares (ha) of small water bodies that have been constructed primarily for irrigational purposes (FAO 1999). Small natural waterways are dammed or strategically placed to collect water during major rainy seasons, in particular the monsoon/seasonal rains, as in Sri Lanka. Once these small water bodies fill, the seasonal rains continue to supply water for downstream farming activities. Over the farming season, the small reservoirs tend to dry-up gradually.

Figure 1. A non-perennial reservoir at high water level. Note that no aquatic macrophytes are found in this reservoir and that water is greenish in colour (Photo: Asanka Jayasinghe)

Figure 2. A non-perennial reservoir in Sri Lanka (after monsoonal rains). Note the presence of aquatic macrophytes. Water is relatively clear compared to that of Plate 1 (Photo: Asanka Jayasinghe)

Table 1. Access characteristics of perennial reservoir fisheries and culture-based fisheries in village reservoirs where group ownership is defined – examples from Sri Lanka (Murray 2004)

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

Figure 3. A non-perennial reservoir in Sri Lanka (same reservoir shown in Figure 1) during the dry season (Photo: Asanka Jayasinghe)

Farming communities who have little or no previous experience with fisheries and aquaculture can develop culture-based fisheries. As such, there is a need to motivate these communities and to impress upon them the benefits of the practices. It is particularly important to explain the complementarity of culture-based fisheries to existing farming practices, and the fact that these practices are not mutually exclusive. It is therefore essential that all available labour is utilised in a pragmatic way to avoid jeopardising ongoing farming practices which will continue to be the main means of livelihood for the community.

Figure 4. A picture of an oxbow lake in Bangladesh. Note that oxbow lakes rarely dry up.

What is the 'better-practice approach' and why is it needed?

Culture-based fisheries are not entirely new, at least for some nations. Some attempts at culture-based fisheries development in the past have been unsuccessful due to many reasons. There are many lessons to be learnt from such failures. These lessons, combined with recent studies, could provide a suitable, adaptive package, incorporating a 'better-practice approach' that will enhance adoption and development as an effective fish production practice amongst rural communities in Asia.

It is important to outline the major factors causing some nations to fail in their attempts to popularise culture-based fisheries in the past. These factors could be common to most nations that are planning to develop culture-based fisheries as a rural fish production strategy. Some of the factors that contributed to previous failures are:

- Lack of sufficient and effective community consultations;
- Lack of cooperation and/or consultation amongst multiple users of the water bodies, often leading to conflicts amongst users and governmental authorities;
- Unavailability of suitable seed stock, often being a problem of timing to coincide with the periodic filling of the water bodies;
- Lack of suitable preparation of the water bodies prior to stocking, e.g. removal of unwanted fish species, including carnivorous species (see Vietnam case study, Section 2.2 for details);
- Ineffective training of potential fish farmers;
- Heavily subsidised developments;
- Inadequate and inappropriate legislation, e.g. in Sri Lanka the small, non-perennial, water bodies, popularly referred to as 'seasonal tanks' are under the jurisdiction of the Department of Agrarian Services, but formerly the Agrarian Services Act precluded any fishery practices in such water bodies; and
- Poor marketing strategies.

The better-practice approach takes these reasons into account, along with recently accumulated scientific, social, and economic knowledge on culture-based fisheries. This approach also provides a comprehensive and a pragmatic strategy to successfully developing culture-based fisheries in rural Asia as an important and significant fish production strategy.

Major steps to be taken into consideration

Community consultations

From a socio-economic point of view, an inherent characteristic in the development of culture-based fisheries is that this strategy involves rural communities, who may not always be familiar with fisheries and aquaculture.

Motivating rural communities, who are familiar with culture-based fishery practices (e.g. those involved in previous culture cycles), to become involved again with culture-based fisheries is not difficult. In some extreme cases, it can be expected that the communities will make decisions on their own (i.e. without intervention by an extension officer).

For communities unfamiliar with culture-based fisheries, an effective mechanism has to be introduced to motivate them to become involved. However, it is difficult, if not impossible, to drive rural communities towards the adoption of decisions made at the higher managerial levels, as central management units often possess little knowledge about the needs and aspirations of rural communities.

When central management units (e.g. the Department of Fisheries or equivalent), researchers or any other group wants to develop a culture-based fishery in a water body situated within a village, through community participation, it is necessary to be knowledgeable of the local situation prior to planning and commencing the activity. An exploratory rapid appraisal (ERA) can be conducted for this purpose. An ERA is an effective means for aquaculture and inland fisheries extension officers to learn, in a limited period, about rural communities and to motivate them to adopt an unfamiliar development strategy. Through an ERA, it is possible to identify the potential problems related to the proposed activity and to decide on priorities. The ERA also helps to raise issues that need to be addressed by further research.

Examples of questionnaires that could be utilised in an ERA are provided in Annex 1. *These questionnaires need to be modified and adapted to suit the needs/situation of each individual nation/region/community.*

ERA methods are a powerful set of tools that can be designed to get communities to identify important issues pertaining to their local setting. One of the most efficient techniques is the preparation of maps/schematic diagrams by local people (e.g. Figure 5). ERAs are a useful means of finding out what the local- communities consider important in their environment, especially in terms of support services required to maintain their livelihoods.

Similarly, seasonal calendars can be drawn by local people to indicate weather patterns, agricultural seasons, fallow periods, seasonal availability of labour and demand for fish resulting from imported labour such as for paddy cultivation practices. Using this information as a seasonal livelihood calendar, which incorporates farming activities and associated trends in fish, demand can often be predicted (Figure 6). Such a calendar enables more effective planning for the culture-based fishery practices, in harmony with other farming activities in a given area.

The above livelihood calendar is based exclusively on climatic and socio-economic activities in Sri Lanka, so may not be directly applicable to other nations/regions. For example in Lao PDR, the main rainy season is May to October, so the most appropriate time to stock will be in June–July and harvest in February–March. In principle, therefore, such a calendar can and should be developed for each nation that proposes to embark on developing culture-based fisheries to facilitate extension and implementation.

Other diagrams prepared by local communities (see Figure 7) can be used to identify current institutional problems that need to be resolved before commencing a development strategy.

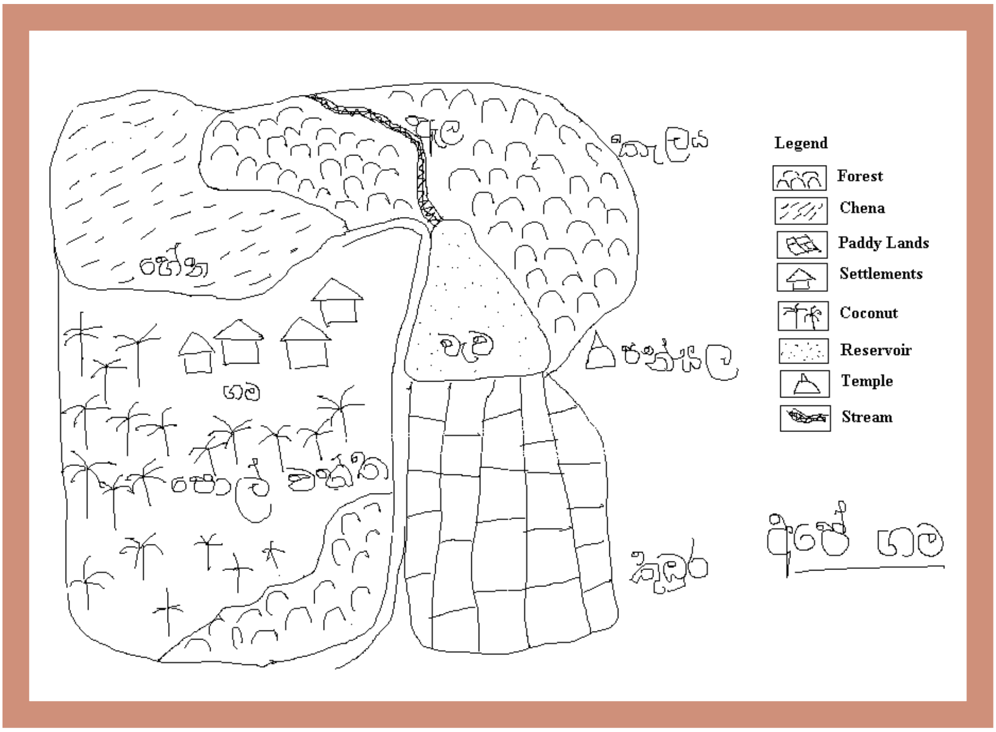

Figure 5. Schematic diagram of a rural village as conceptualised by a village community in Sri Lanka.

An effective mechanism to learn about the priorities and preferences of rural communities is to request members of the community to do a simple exercise. For this purpose, groups with some basic knowledge about the proposed development activity should be identified and requested to list priorities and preferences for developing a culture-based fishery in the area.

Participatory rapid appraisal (PRA) is a tool to motivate local people to analyse their own conditions, suggest solutions and organise themselves to implement these. Here the participants should be divided into small groups of manageable sizes. The members of these groups should not necessarily be homogeneous in terms of age, gender and livelihood amongst other factors, but they should have some common interests (e.g. live in the same community; be engaged in similar type of work; or belong to one caste/ethnic group or social class). Here, the facilitator should spend some time to become familiar with the community. The members of the community should be requested to gather at a mutually convenient time at a suitable place (e.g. meeting hall of the farmers' organisation). The facilitator should explain why he/she is there, and should emphasise that the purpose of this meeting is not to give away credit or subsidies. Various approaches should be used to create a relaxed atmosphere (e.g. by organising simple games, or by telling stories and jokes, which can be related to the topic to be discussed).

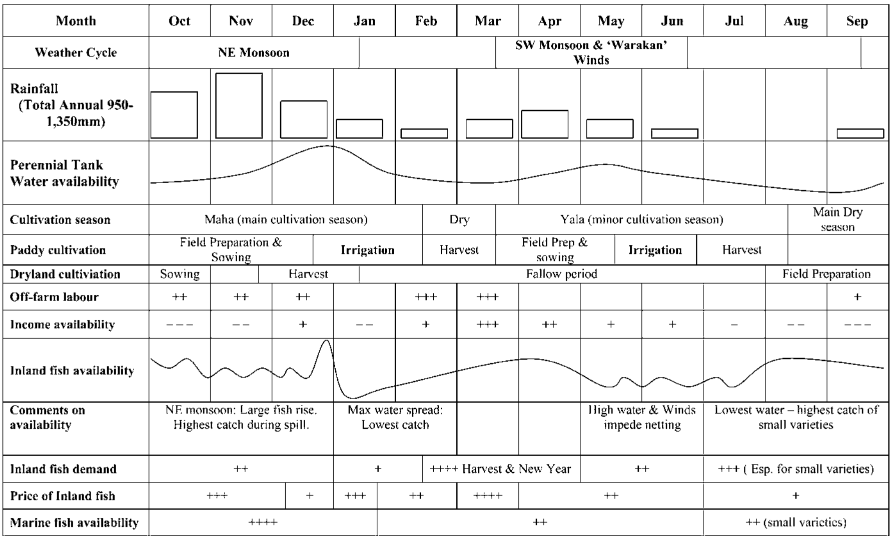

Figure 6. Seasonal livelihood calendar (farmers) and inland fish market trends, Galgmuwa and Anamaduwa District, Sri Lanka, 1998–99 (Source: Interviews with farmers, fish producers and vendors). Note: +++ = greatest amount, --- = lowest amount (Source: Murray et al. 2001).

The following steps should be preferably adopted in PRA methods:

1. Participants of the meeting should be requested to suggest a few main problems (five is a suitable and manageable number) and these problems should be listed in order of priority. If the participants are not literate, one of the team members need to note down the comments of members of the group.

2. Problems identified by each group should be presented to other groups and these problems should be grouped into related categories. This will help to identify principal problems.

3. Individual members should be requested to list the resources available (physical resources such as land, water, fish, man-power, funds, etc., and non-material resources such as education, skills, experience, desire to change, etc.), which can be used directly and or indirectly for culture-based fisheries development and facilitation.

4. The problems identified can then be compared with the resources available.

5. A discussion should be initiated about why these resources have not been utilised. Based on this, participants should be encouraged to identify an action plan.

6. Finally, a plan of action should be prepared for discussion and collective agreement reached.

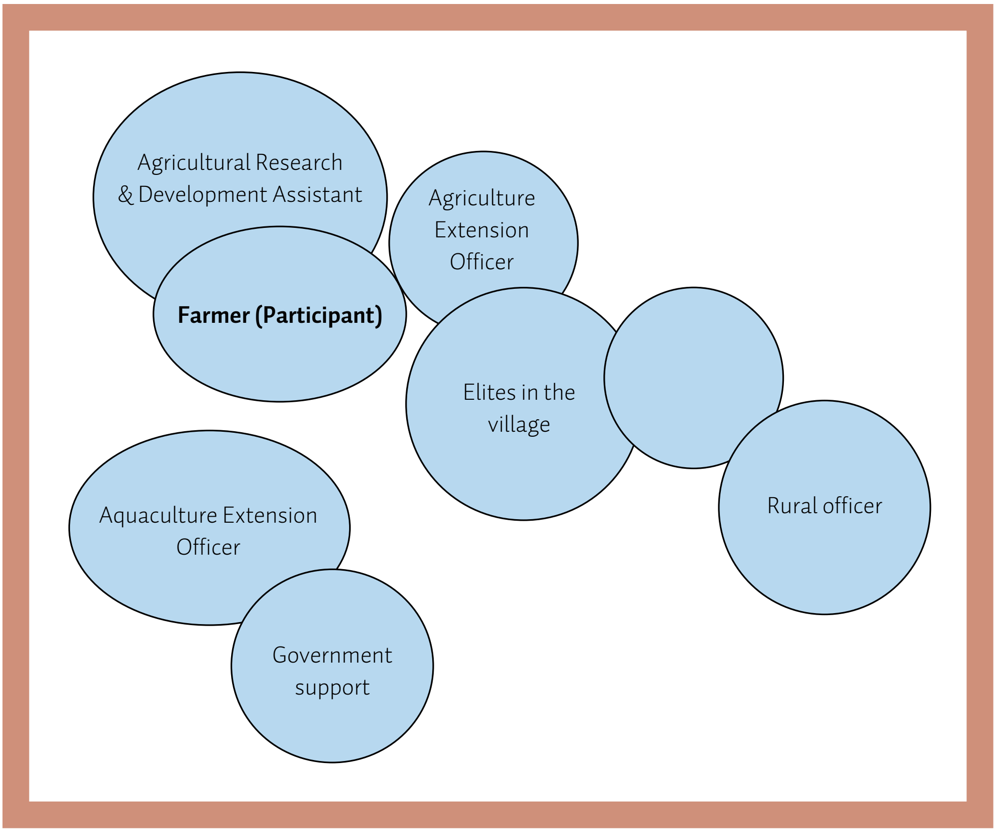

Figure 7. An example of a diagram that a community has prepared to indicate their strong links to the institutions/persons (overlapped circles) and weak relationships (non-overlapping circles).

Selection of water bodies

Culture-based fisheries are a type of aquaculture in a relatively infant stage of development. As an aquaculture practice, it should aim at benefiting the local community and maximising profit strategies to be successful and sustainable. Therefore, fisheries managers, extension officers and farmers need to have a clear understanding of how to maximise profits and benefits for the community. To this end, the most suitable water bodies need to be selected at the initial stage.

Culture-based fisheries are practiced in small perennial water bodies such as oxbow lakes in Bangladesh and small non-perennial reservoirs in Sri Lanka and Vietnam. The suitability of a water body for the development of a culture-based fishery is based on three factors:

- Physical and biological aspects of the water bodies;
- Socio-economic conditions of communities that live in the vicinity; and
- Socio-economic conditions of the potential practitioners and primary stakeholders of the planned activity.

As a communal practice, socio-economic factors are very important for the development and sustainability of culture-based fisheries. Although a water body may be highly productive, culture-based fisheries practices in it are unlikely to succeed if the community participation is not effective.

Physical and biological aspects of water bodies

Water retention period – This period is an important factor for non-perennial water bodies. The water retention time should be more than six months for carp polyculture and for that matter any form of fish culture to yield good results. If the water retention period is less, the stocked species are unlikely to reach a marketable size. The water retention period is mainly dependent on the water yield of the catchment of each water body, volume and its command area (i.e. the downstream irrigated land area). The main purpose of non-perennial reservoirs in Sri Lanka, for example, is irrigating downstream paddy lands. If the water requirement for the command area is higher than the reservoir capacity, the water retention period of the reservoir will be reduced.

Depth and surface area – These two criteria are also important for determining the water retention period. The surface area often provides an indication of the number of fingerlings to be stocked (discussed in section 1.3.5). Also, a low water depth influences the growth of aquatic weeds and tends to be turbid from wave action. This reduces natural productivity which supplies the food organisms for the stocked fish.

Aquatic plants – As a result of light penetration to the bottom, aquatic plants grow well in shallow water bodies. The presence of aquatic plants negatively affects their productivity and culture practices in a number of ways. These are:

- Floating leaves of aquatic plants, such as water lilies and lotus, cover the water surface reducing light penetration in the water column. Low light intensity will reduce the growth of algae/phytoplankton—a food resource of some of the stocked species—in the water column.
- Dissolved nutrients are absorbed by aquatic vegetation reducing nutrient availability for plankton growth.
- Aquatic plants provide a place where predatory birds can rest.
- Wide coverage by aquatic plants makes harvesting difficult so extra effort and money has to be expended to remove these prior to harvesting.

The combined effect of the above factors significantly reduces fish production in water bodies (Figure 8).

Submerged tree stumps and obstacles – Submerged stumps and other obstacles also make harvesting difficult, especially as they act as barriers to the operation of seine nets. The presence of such barriers leads farmers to use different types of gear, thus they expend extra effort to harvest. Tree stumps and obstacles also provide roosting substrates for piscivorous birds (Figures 9 and 10).

Presence of carnivorous species and piscivorous birds – The presence of predatory fish affects culture-based fishery yields in two ways. Firstly, carnivorous and piscivorous species prey on stocked fish; and secondly, they can reduce the growth of seed stock as a result of predatory stress. Predatory fishes can enter a water body through interconnected canals and/or can be native to the water body. Results of culture based-fisheries in non-perennial reservoirs, which are interconnected through cascades to large perennial reservoirs, show a considerable proportion of snakeheads (*Ophicephalus* spp. and *Channa* spp.) in the yield and high mortality of some stocked fish species (Figure 11).

Productivity of the water body – Phytoplankton abundance in a reservoir determines its productivity. Basically inland water bodies can be divided into four groups according to their productivity levels: *oligotrophic*, *mesotrophic*, *eutrophic* and *hyper-eutrophic*. Although water bodies are classified into different trophic groups, those with high chlorophyll levels are favourable for culture-based fisheries. Visual observation of water bodies gives a relative measure of productivity levels. Clean water with good light penetration indicates low production, as does turbid water with high levels of suspended clay and mineral particles. When water is green, it indicates that the water body has good production potential for culture-based fisheries development.

Cattle rearing practices around water bodies – Water buffalo and cattle rearing are common in rural areas in the region. This animal husbandry practice has a positive influence on the nutrient loading of the water body. Especially in dry periods, cattle and buffaloes graze in the open bed. Their urine and dung supply considerable amounts of nutrients. However, water buffalo and cattle can also have a negative influence by making the water body turbid, thereby impeding primary production and limiting food availability for the fish.

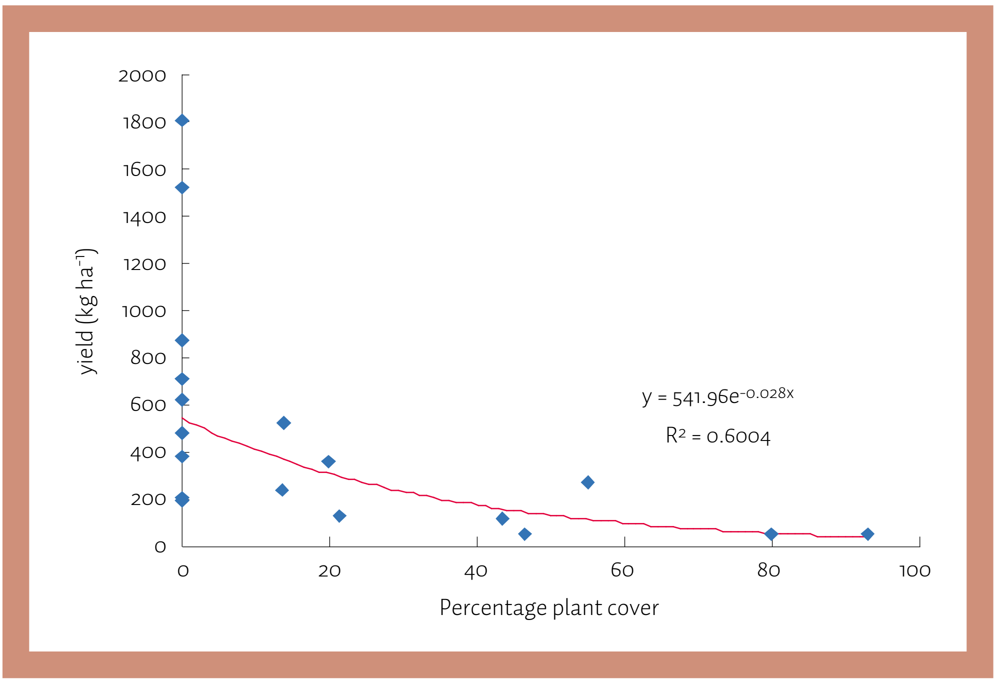

Figure 8. Relationship between percentage plant cover and fish yield in non-perennial reservoirs of Sri Lanka.

Figure 9. Reservoir bed without impediments for operating fishing gear (Photo: Asanka Jayasinghe).

Overall, however, it is believed that the influences are positive, even though quantitative information in this regard is still lacking.

Catchment characteristics of water bodies – The catchment area of a water body is important as a source of allochthonous inputs. Disturbances in the upper catchment area can increase soil erosion and the silt loading. It is very important therefore to minimise disturbances and agriculture practices in reservoir catchments.

Accessibility – Accessibility to a water body is important at the stocking and harvesting stages. It is advantageous to have close accessibility to a fingerling rearing station to minimise the stress on seed stock during transportation. Easy accessibility also facilitates marketing and also enables obtaining a better price for the produce.

Socio-economic aspects

Willingness to be engaged in culture-based fishery practices – Culture-based fisheries require community participation. If the community does not have a desire to be engaged in fishery practices, possibly for various reasons, a culture-based fishery will not succeed. Although most people engaged in culture-based fisheries are not primarily fishers, community willingness is essential.

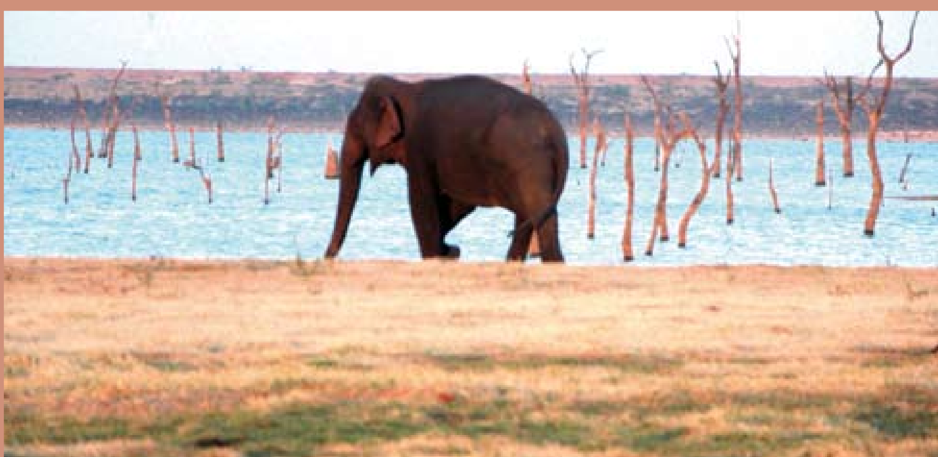

Figure 10. Reservoir with submerged tree stumps which act as impediments to fishing (Photo: F. M. Farook).

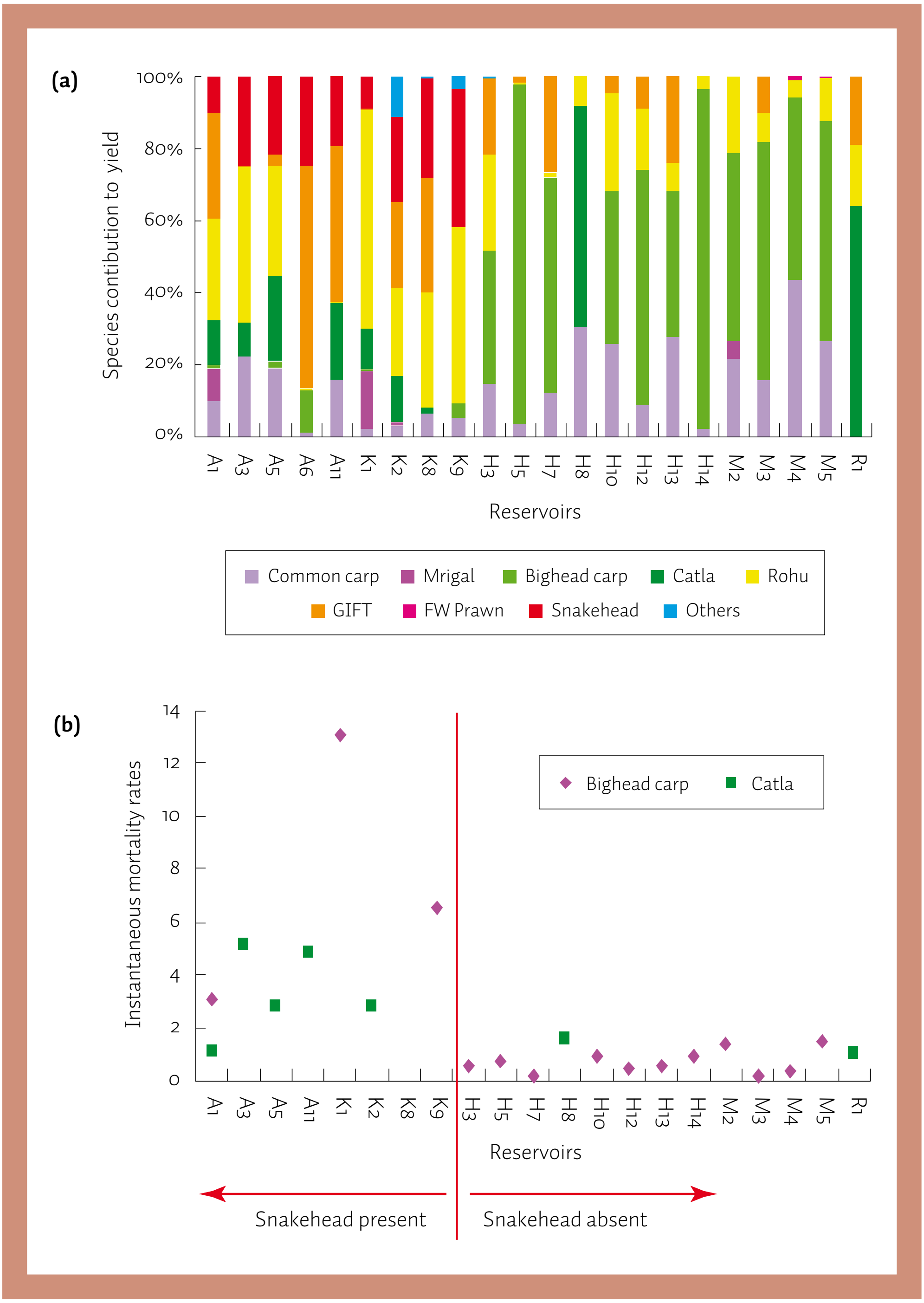

Figure 11. (a) Percentage contribution of species to the total yield of reservoirs; (b) Instantaneous mortality rates of bighead carp and catla in non-perennial reservoirs of Sri Lanka.

Previous experiences – Development of culture-based fisheries may be influenced positively as well as negatively by previous experiences. If a community has experienced previous benefits and satisfaction from fishery practices, there will be a desire to continue. Whereas a community who experienced conflict during previous attempts generally will not favour continuing aquaculture practices in the water body in which they have a stake.

Multiple use of water bodies – Most reservoirs are water bodies with multiple uses. Culture-based fishery practices in reservoirs have the potential to create conflicts within a community. In some dry areas, the reservoir is the main water resource for bathing and cleaning. Fish harvest at low water levels creates conflicts between general water users and fish farmers. Also the release of water for crop cultivation can reduce the water level creating unfavourable conditions for fish growth.

Strength of community organisations – The strength of community organisations significantly impacts the sustainability and development of culture-based fisheries. Leadership, socio-economic heterogeneity and education level of the whole community are critical factors. Collectively, these factors underpin the effectiveness of a community's decision-making and cooperation. Good leadership in a community facilitates better communication between government officers and village-level organisations. This is vital for knowledge transfer to rural communities, and conflict resolution amongst local communities.

Market demand for inland fish – In most instances, preference for inland fish depends on the availability of marine fish in the market and inland fish supply. However, there are exceptions in the region. Also, in general, most rural communities in the region tend to prefer indigenous fish to exotic fish, and wild caught fish to "farmed" fish. Availability of wild caught fish is seasonal however. It is therefore vital, in particular, to plan harvesting, whenever possible based on market price fluctuations

Summary of steps to be taken in initiating the development of a culture-based fishery practice in a water body with common access in a village

- Conduct an ERA- exploratory Rapid Appraisal to determine the willingness of the community to participate in the proposed activity
- Conduct a PRA- Participatrory Rapid Appraisal to determine incorporation of indigenous knowledge in relation to the related activity
- Organise a "fish farming" group within the community in concurrence with all the stakeholders to the water resource
- Determine the suitability of the water body for developing a culture-based fishery practice based on socio-economic conditions of the participating community and the physical and biological featured of the water body

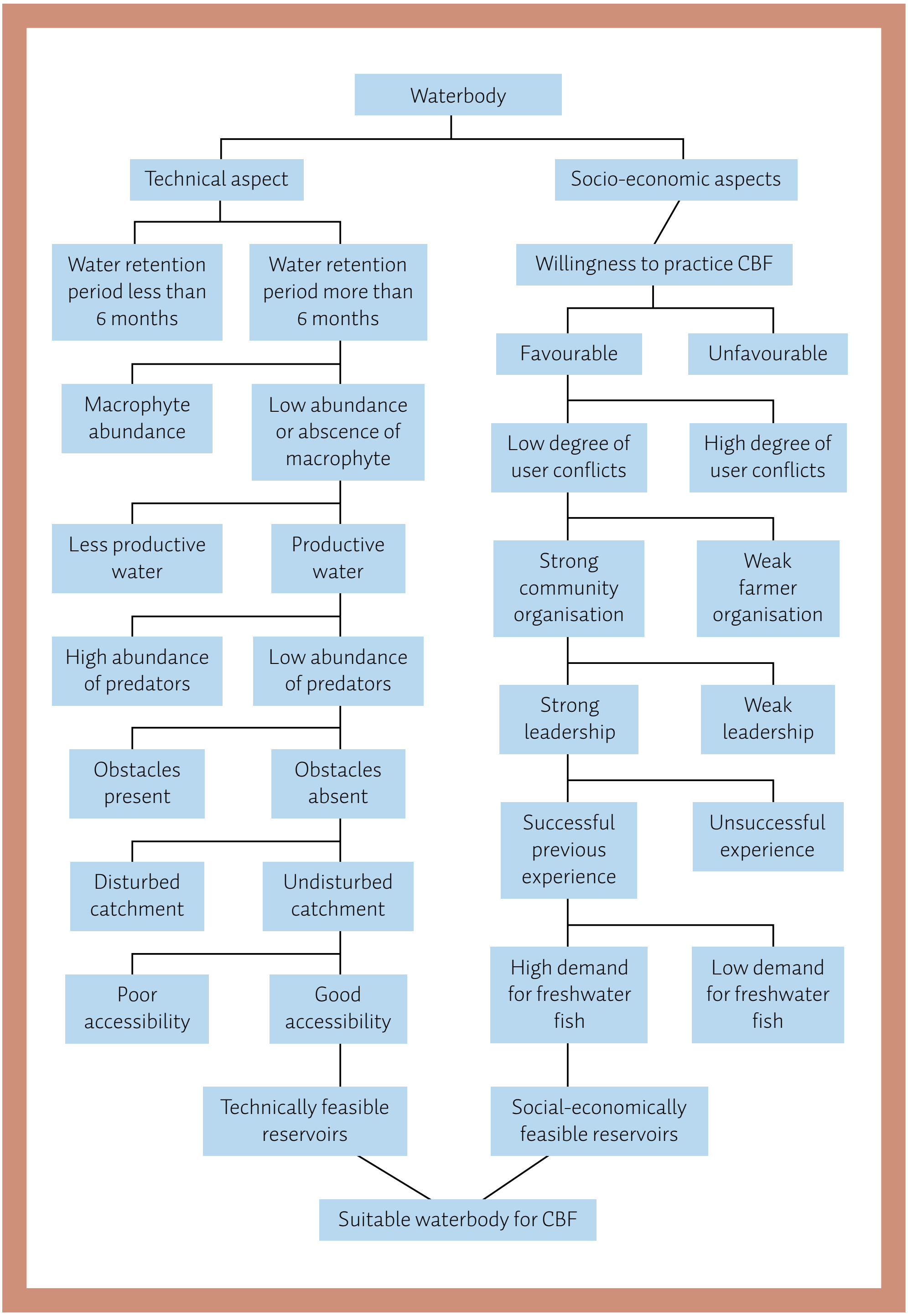

Figure 12. Flow chart for selecting suitable water bodies for culture-based fisheries.

and availability of wild caught fish in order to maximise returns. However, it is important to note that the consumption of inland, freshwater fish has increased by over ten-fold between 1981 and 1997. This amounts to about 20–25% of the animal protein intake by rural populations in the developing world (Delgado et al. 2003), and as such a properly planned harvesting strategy will facilitate and will enable farmers to obtain reasonable prices for their culture-based fishery produce.

The factors presented above are summarised in the flow chart in Figure 12.

Species selection

After the selection of a water body, the next step is to decide which species should be stocked and in what quantities. To select an appropriate species for culturing, consideration of the farmers' knowledge and previous experiences in culture-based fisheries are important. The availability and relatively easy access to seed stocks of appropriate species, when required, is another important consideration. For example, there are many non-perennial reservoirs in Sri Lanka with dense aquatic vegetation cover, but fingerlings of grass carp are often not available for stocking such water bodies.

As culture-based fisheries are a form of extensive aquaculture, the species used should be those preferred for any type of culture. Desirable features for a cultured species include the:

- Market demand for that particular species – because the ultimate goal of culture-based fisheries is to gain profit by selling the surplus yield.
- Acceptance as a food fish to the surrounding communities – this matters significantly if the cultured fish is different from the conventional food types of that particular geographical region, and if the consumers do not know how to process or cook the species in a suitable way.
- Ability to depend on the available natural food resources within the water body in a short food chain, i.e. fish species that depend on phytoplankton, zooplankton and detrital aggregates should be stocked rather than piscivorous/carnivorous species feeding high on the food chain.
- Fast growing and efficient converters of food enabling them to reach a marketable size within a short period of time, generally six to nine months. This is particularly important if the water body is not perennial.
- Inability to breed within the culture system – this is important when the selected species are exotic. Firstly, the food consumed by the stocked species should be used primarily for growth and not diverted to form gametes; and secondly, preventing the establishment of breeding populations in other waterways will avoid long-term effects on biodiversity.
- Ability to co-exist with other species in a water body to maximise the use of available space and productivity – this is commonly known as polyculture. Since there are various types/forms of natural food items within a water body, different species consuming different food items can be farmed together without any conceivable competition for food and or space (Figure 13). Depending on the available food items, the water column can be divided into three layers: top, middle and bottom. Microscopic plants known as phytoplankton (Figure 14) are generally abundant in the top layer. Therefore, fish species feeding on phytoplankton occupy

the top layer. Likewise, microscopic animals known as zooplankton (Figure 15), which are found in middle layer, support zooplanktivorous fish. The decaying plant and animal matter known as detritus and benthic animals found in bottom layer support bottom-feeding fish species.

Based on international experience in culture-based fisheries, it is accepted that the major Chinese (grass carp- *Ctenopharyngodon idellus*, bighead carp- *Arstichthys nobilis*, silver carp- *Hypophthalamichthys molitrix*) and Indian carps (catla- *Catla catla*, mrigal- *Cirrhinus mrigal*, rohu- *Labeo rohita*) and the common carp (*Cyprinus carpio*) have most of the desired features for culturing. In some instances tilapia species also may be used. Images of these species with brief descriptions are provided in Figures 16–23.

There is an increasing emphasis in the region, particularly in countries such as Cambodia and Lao PDR on the use of indigenous fish species in aquaculture related developments, primarily based on potential negative impacts on biodiversity from alien species. It is not opportune to delve in to the pros and cons of the alien versus indigenous issues at this juncture. However, it is important to note that improper use of hatchery bred stocks of indigenous stocks in aquaculture related activities and in stock enhancement of large water bodies could be equally detrimental. Secondly, some nations may not have suitable indigenous species for culture-based fisheries and or for conventional aquaculture developments, and therefore may have to rely on alien species to augment fish food supplies in rural areas.

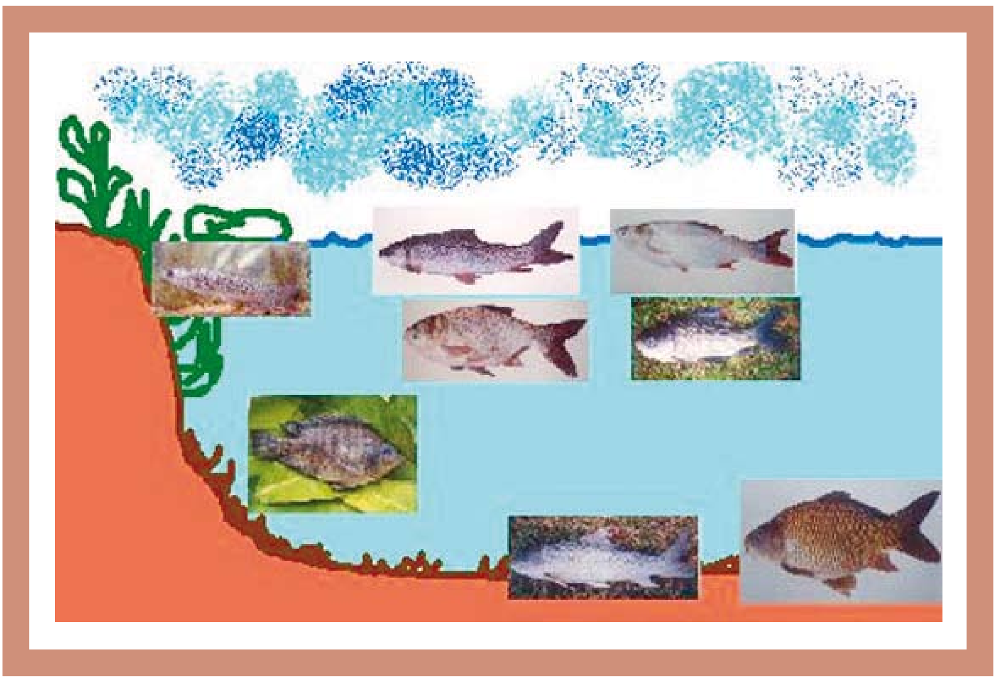

Figure 13. Fish species occupying different ecological niches in a water body.

Figure 14. Microscopic plants known as phytoplankton (Source: Department of Zoology, University of Kelaniya).

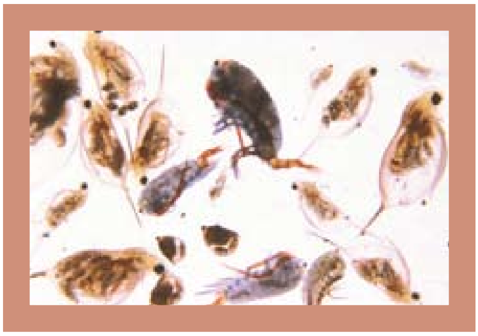

Figure 15. Microscopic animals referred to as zooplankton (Source: http://www.uga.edu/srel/ESSite/Barbara_Taylor.htm).

Preparation prior to stocking

Eradication of unwanted organisms and potential predators

Most piscivorous species eat small-sized fish. Snakeheads, walking catfish, climbing perch, goby species, eels and sting catfish are some examples of common predatory fish species in freshwater bodies of Asia. Some precautions have to be taken in culture-based fisheries to enhance the survival rates of stocked fish. Precautions include:

- Eradication of predatory species in the water body usually done using a biodegradable toxicant such as bleaching powder, tea-seed cake, etc;
- Complete harvest of the existing fish species;
- Complete drying-out of the waterbody, if non-perennial; and
- Establishment of barriers across inflowing streams and channels to prevent predator access. Frequently small mesh size nets are used to make barriers.

Fingerling supply

The ready supply of hatchery-reared fish fingerlings at the correct time is one of the pre-requisites for sustainability of culture-based fisheries. In some systems, such as the non-perennial reservoirs of Sri Lanka, stocking time is determined by climatic factors i.e., monsoonal rains in November–January when reservoirs fill. Rural agricultural farmers carry out culture-based fisheries practices as a part-time activity. Thus, they are unable to rear fingerlings as it requires almost continuous involvement of a person or persons. Consequently, a mechanism is needed to supply fingerlings to culture-based fishery systems.

Demand for fish fingerlings in some culture-based fisheries systems (e.g. the non-perennial reservoirs of Sri Lanka) cannot be predicted because it is determined by natural factors. Consequently, the farmers rearing fish fingerlings must have an alternative means of selling their product.

In this context, the effective mechanism to sustain a culture-based fishery is to form a cluster of rural organisations, which includes the following rural institutions/community groups:

- Hatchery owner (state or private) (and aquaculturist);
- Fish farmer/aquaculturist for rearing post-larvae to fry stage (pond owner);
- Fish farmer for rearing fry to fingerling stage (ponds, cages and pens);
- Fishing/agricultural community of a minor perennial reservoir (<250 ha), who have a stake on the water management, members of which are willing to stock the water body to establish a stocking–recapture fishery– and the true culture-based fishery component in the chain of activities.

This type of cluster links culture-based fishery practices to other aquaculture practices in the area, and will generate synergies that would be advantageous to all.

This approach also assures a ready supply of fish fingerlings to culture-based fishery practices in a region. When fish fingerlings are not required for stocking water bodies for culture-based fisheries, these can be sold to fishing communities in minor perennial reservoirs and other fish farmers. Among these communities, sale-assurance agreements can be signed to develop trust between them. The possible links between various rural institutions are shown in Figure 24.

Figure 16. Rohu (*Labeo rohita*) – This Indian carp feeds primarily on phytoplankton. There is a dark blotch on caudal peduncle. Fins are pinkish in appearance. Mouth sub-terminal with thick suctorial lips.

Figure 17. Bighead carp (*Aristichthys nobilis*) – Chinese carp mainly feed on zooplankton. Large head relative to the body size is a characteristic feature. Body scales are minute.

Figure 18. Catla (*Catla catla*) – This Indian carp mainly feeds on zooplankton. Head is large with increased body depth before the dorsal fin.

Figure 19. Common carp (*Cyprinus carpio*) – This carp has a worldwide distribution. Body depth is high with yellowish appearance. Mainly feeds on detritus.

Figure 20. Grass carp (*Ctenopharyngodon idella*) – This is a major Chinese carp that feeds on aquatic weeds and marginal vegetation. Body is silver in colour and elongated.

Figure 21. Mrigal (*Cirrhinus mrigala*) – This Indian carp mainly feeds on detritus. Elongated body with bluish silver appearance.

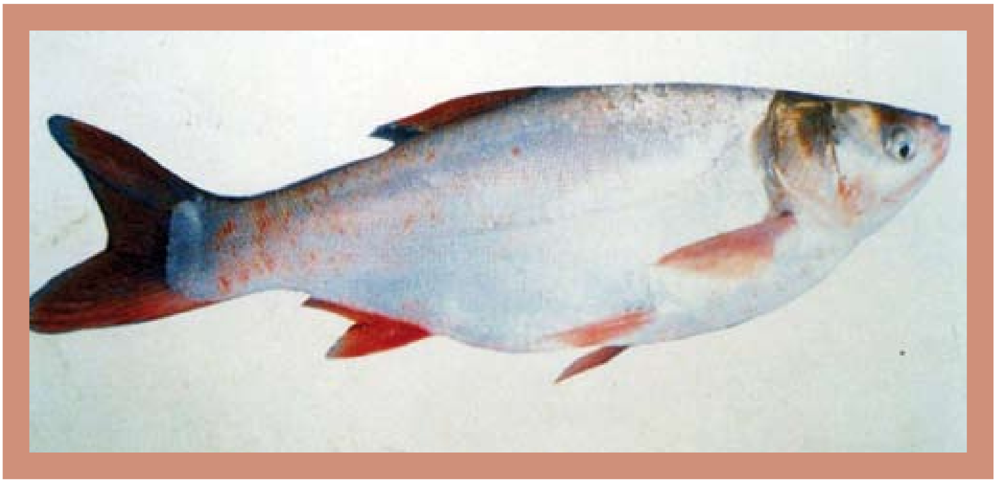

Figure 22. Silver carp (*Hypophthalmichthys molitrix*) – This Chinese carp mainly feeds on phytoplankton. Small head relative to the body size is a characteristic feature. Body scales are minute.

Figure 23. Nile tilapia (*Oreochromis niloticus*) – This cichlid from Africa has a worldwide distribution. Feeds on almost all plant and animal matter in water column. Dark body and fins are with black vertical lines.

Much is known about fingerling transportation and stocking procedures. The main points that need to be taken into consideration are:

- Prior to transportation, all fingerlings need to be starved for 24 hours to ensure that the guts are clear of any food;
- Fingerlings should be packed in a suitable container, e.g. double-lined, thick-walled polythene bags, containing about 1/3 the of water of the volume of the bag, slightly anaesthetised with a mild anaesthetic, if available, and filled with oxygen and tightly secured to prevent any escape of oxygen;
- The containers with fingerlings should be transported to the site, under cover, avoiding transportation at high temperatures;
- On arrival at the site, prior to stocking, the bags should be placed in the water body, avoiding direct sunlight, for one or two hours, to enable the water temperature in the bag to reach that of the water body and to permit the fingerlings to 'calm' down;
- Fingerlings should then be released slowly by opening the bag/container. This is best done in the early hours of the morning or late in the afternoon, after the sun has set.

Stocking size

The size of fish at the time of stocking is a major factor determining the final fish yield in culture-based fisheries. If small fish are stocked, the risk of natural mortality is higher. Since the culture system is a natural water body there may be predatory fish as well as birds in the surroundings. Small-sized fingerlings would be ideal sized prey for these natural predators. Therefore, advance fingerlings or fish more than 10 cm in length are preferable in order to enhance survival rates. Also, there could be differences in the preferred size at harvesting, amongst countries, and as such the stocking size needs to be determined accordingly. For example, in China the preferred stocking size is 15 to 17 cm and 25 to 30 g fish. In Vietnam the preferred stocking size is about 50 g fish, where as in Sri Lanka it is 10-15 g fish.

Summary of physical and biological criteria that are to be used in determining the suitability of a water body for developing culture-based fishery practices

- Period of water retention; should be at least 7 to 9 months
- Vicinity to the farming community and potential markets
- Relatively undisturbed catchment
- No major conflicts between water users
- Minimal spread of rooted or floating macrophytes
- Lack of tree stumps and similar obstacles
- Potential high biological productivity

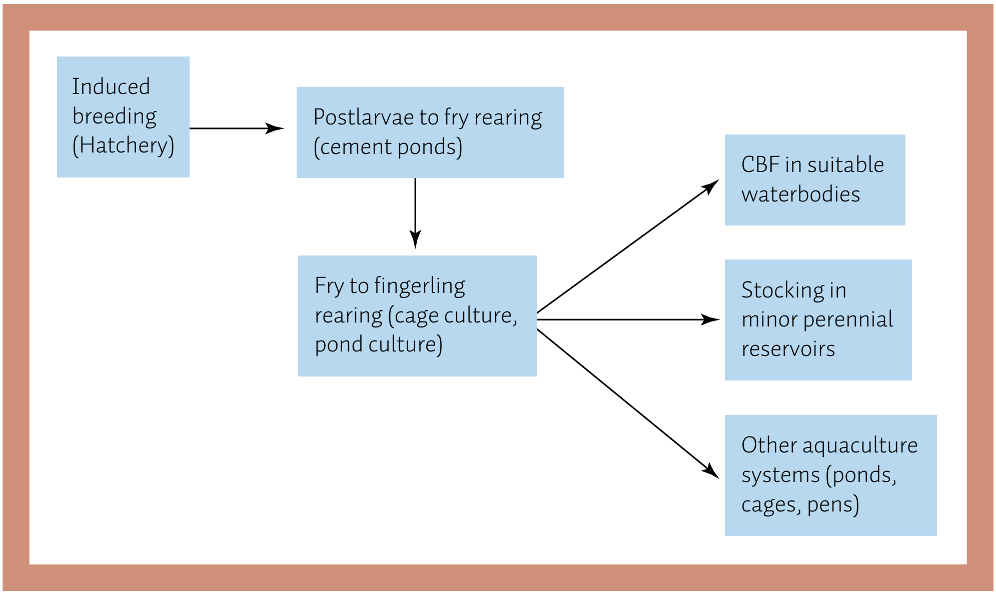

Figure 24. A schematic representation of the cluster of farming activities that is likely to generate synergies and increase the sustainability of the individual activities.

At stocking, the selected species combination should consist of more fish that –feed on phytoplankton than zooplankton (Figure 25) since the amount of zooplankton in a water body is always less than the amount of phytoplankton.

Stocking density

Stocking density can be expressed as the number or weight of fingerlings per unit surface area to be stocked in a selected water body (i.e. no./ha or kg/ha). To determine the suitable stocking density for a particular water body, estimates of the surface area of the water body and the availability of natural food resources are required.

Various stocking experiments around the world have shown that the final fish yield increases with increasing stocking density up to an optimum level and then begins to decrease (Figure 26). This is due to the limitations in space and food availability for the growing fish. Normally, the optimum stocking density lies between 2000 and 3000 fingerlings per hectare. Therefore, the appropriate stocking density for a particular system or region should be determined after investigating the trophic conditions of the water in that region.

Supplementary food and feeding

In culture-based fisheries, unlike pond and cage culture, feeding the fish on a regular basis is not essential. However, it is not uncommon to see some farmers using supplementary feeds, such as cassava flour, rice bran for example, which can be purchased locally at a very low price. The direct nutritional impacts of such ingredients, and/or ingredient mixtures, are little known, but they could have a fertiliser effect and enhance natural food

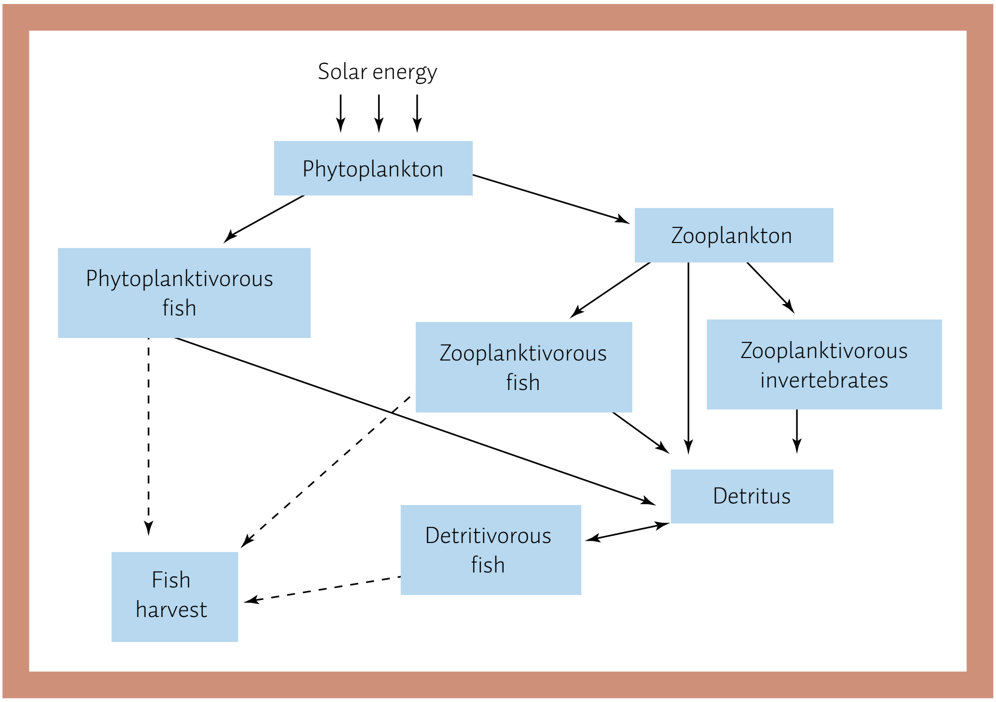

Figure 25. Schematic diagram showing the relative amounts of plankton and fish in a water body.

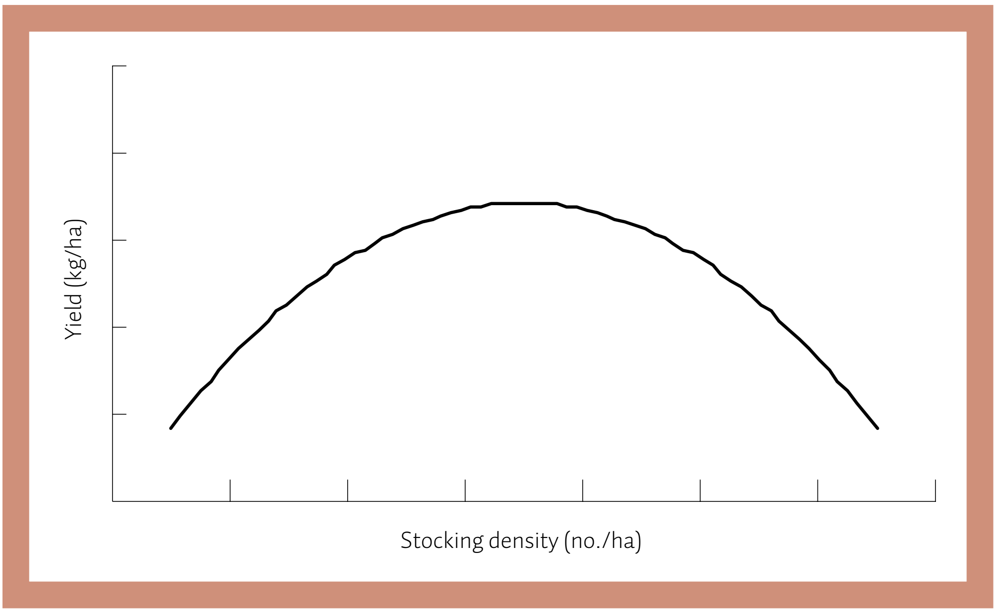

Figure 26. Change of fish yield with stocking density.

production. If grass carp is stocked and the water body lacks sufficient macrophytes, it is necessary to feed grass or another suitable macrophyte, on a daily basis. When grass is fed, it is important to provide a device so that the grass is confined to a specific area in the water body and the fish will soon learn to come to this area to feed (Figures 27 and 28).

The lack of, or minimal, expenditure on feed in culture-based fisheries has two major advantages over conventional aquaculture. These are:

- Direct cost savings on feed as well as on labour; and
- Does not add nutrients to the waterbody and so does not contribute to eutrophication of downstream waters, unlike conventional aquaculture practices

Harvesting strategies

General aspects

In culture-based fisheries almost all fish from a water body are harvested, efficient methods have to be employed. Harvesting should be completed in the early hours of the morning to enable fish vendors to purchase the harvest, as well as reduce chances of spoilage. The amount of fish to be harvested per day should be determined in accordance with demand. If fish are sold to fish vendors who take fish to local markets, it is usually sufficient to harvest 50–100 kg of fish. It is not uncommon for some fish vendors to purchase large quantities of fish (in the range of 1000–1500 kg) and pack them in ice before transporting in lorries to urban markets. It is therefore necessary that

Figure 27. A rope to prevent the drifting of grass; fish soon learn to come and feed in this enclosed area (Vietnam) (Photo: Sena De Silva).

arrangements be made in advance with fish vendors before large quantities of fish are harvested from a water body.

If harvesting is done in small quantities for selling to local communities, gillnets of stretched mesh sizes of 10.2–14 cm can be used to harvest bighead carp, silver carp and catla depending on the growth of stocked fish. However, a fishing craft is needed for this purpose. Dragnets or seine nets can be used to catch rohu, common carp and mrigal. The cod-end mesh-size of this net should be 5.2–6.4 cm. Fish harvested from a water body can be kept alive for a short period by placing them in holding cages. These cages can be left floating in the reservoir.

Special considerations

Communities involved in culture-based fisheries are mostly rural crop farmers rather than permanent fishers. It is noteworthy to trace some of the developments in culture-based fisheries in Sri Lanka, which may have relevance to some other nations. At the commencement of culture-based fishery practices in Sri Lanka, farming communities who had the responsibility for managing the small water bodies leased the water bodies to coastal fishers who had their own fishing gear. In these instances, the whole catch was sold outside of the village. Over time, the village farming communities began to realise that direct involvement in culture-based fisheries would be more advantageous than leasing.

Figure 28. Macrophyte collection for feeding grass carp (Vietnam) (Photo: Sena De Silva).

Preparation of a water body for a culture-based fishery practice

- Ensure, as far as possible, that unwanted, predatory fishes are eradicated
- Erect simple (net) barriers at all inflows to the water body
- Determine the most appropriate time to stock based on the time when the water body is likely to reach full level
- Determine species combination and numbers of each to be stocked, based on available information and in consultation with relevant fishery extension officers,
- In determining the above take into account easiness to obtain seed stock and marketing potential
- Prepare a roster fro guarding the seed stock

At the second stage of the culture-based fishery development, farmers harvested the fish themselves. However, in most instances the available facilities were not adequate for harvesting. In particular, rain-fed, non-perennial reservoirs dried up at the same time, so harvesting gear was in high demand during this short period. The non-availability of gear led farmers to harvest the water body within a few days. This created severe marketing problems. As a result of over flooding the market, the value of the harvest was significantly reduced. Unavailability of gear forced farmers to hire gear from outsiders. The farmers proposed two options to resolve the problem in Sri Lanka. The first one was to supply two to three sets of gear to *Govijana Kendraya* (grass root level agriculture extension office). The second option was to establish the facility to hire gear from a central agency responsible for fisheries/aquaculture development, such as the National Aquaculture Development Authority (NAQDA), in the case of Sri Lanka.

Harvesting should essentially be done through community participation. As villagers usually consider that they have some level of ownership of the resource, a nominal amount of fish (about 1 kg per family) can be given, free-of-charge, to the villagers who take part in harvesting.

Income sharing agreements

Culture-based fisheries are essentially developed in water bodies that generally are *communal property* or *common pool property.* That is, an identifiable group of people makes use of a resource for various purposes. Once such water bodies are stocked for the development of culture-based fisheries, ownership should be defined because the economic benefits should go to the active partners of the development strategy. This can lead to conflict with the villagers who had access to the resource before stocking with fish fingerlings, for example conflict may arise between pleasure fishers and those involved in the culture-based fishery. However, this problem may not arise in small communities if all members of the community are involved in the culture-based fishery. If a small group of the community is engaged in this activity, there should be an arrangement to pay the rest of the community some compensation for the loss of their user rights. The community can arrive at a satisfactory agreement at the planning stage when the decision is made to develop a culture-based fishery. Meetings about existing institutional arrangements, such as when farming communities decide the water sharing procedure for agricultural lands or meetings of rural welfare societies can be used as a forum to develop effective mechanisms. In Sri Lanka for example, a meeting of the downstream farming community is held on a regular basis to determine the water use procedures for the current cultivation period.

In Sri Lanka, sub-committees of farmers' organisations of non-perennial reservoirs, which are assigned to develop culture-based fishery practices, arrive at agreements to pay 5% to 100% of the net profit to the farmers' organisations. The amount varies according to the size of the community. In small communities (<20 members), usually all members are involved in culture-based fisheries, so the entire profit is shared amongst all members.

It is also necessary to set aside funds for purchasing fingerlings for the next culture cycle. For this purpose, a revolving fund can be established and a certain percentage of profit can be added to the fund to ensure the sustainability of the culture-based fishery practices.

In Vietnam, the provincial authorities auction the water bodies either to individuals or groups of individuals. As such, the community gains indirectly through an increase in the revenue of the provincial government as a result of culture-based fishery practices.

Marketing

As mentioned previously, harvesting should be completed in the early hours after sunrise to enable fish vendors to purchase the fish. Proper marketing channels (often site-specific) should be developed for culture-based fisheries as they have been for most capture fisheries. To this end, a marketing survey is required. As part of this survey, the existing marketing network for marine and freshwater fish in the area needs to be identified. Seasonal variation in the demand for fish should also be taken into consideration. For example, in Sri Lanka, demand for freshwater fish increases during periods of ploughing and harvesting in paddy cultivation due to imported labour for seasonally labour-intensive agricultural practices.

Rural culture-based fisheries products can be consumed by local communities and/or be traded at local markets. This section focuses on trade. Market problems associated with rural fishery products and potential strategies help to overcome such problems are also presented in this section.

Market chains

Most rural fishery products are aimed at local buyers who live near the production areas. These fishery products are mostly traded in the markets within one-to-three hours of travel time from the original supply sources.

To examine the market chains/flows for rural culture-based fishery products, suppliers and buyers need to be considered.

Suppliers — In this context, suppliers are the culture-based fish farmers who are the primary supply source of the rural culture-based fishery products, which include exclusively fish and possibly prawns.

Buyers — Although 'buyer' is a simple title, it is used as a consolidated term to include all related trade parties of rural culture-based fishery products. The demand-end of the market chain is rather complicated (Figure 29). Buyers in this context include:

- Traders, wholesalers and/or middlemen who buy directly from fish farmers and sell it to other buyers in the local market or to markets not accessible to fish farmers. This group usually has strong financial backing.
- Local restaurants and/or food stores who buy direct from fish farmers or from traders or wholesalers, depending on the accessibility to the supply sources. They resell the products in cooked form to consumers.
- Fish vendors at local wet markets who buy direct from fish farmers or from traders or wholesalers, depending on accessibility to the supply sources. They resell at local markets to household consumers. Sometimes small local restaurants or food stores will buy from fish vendors at the markets.
- Ad-hoc visitors or tourists who buy directly from fish farmers when they visit production sites. These transactions are less likely to be repetitive.

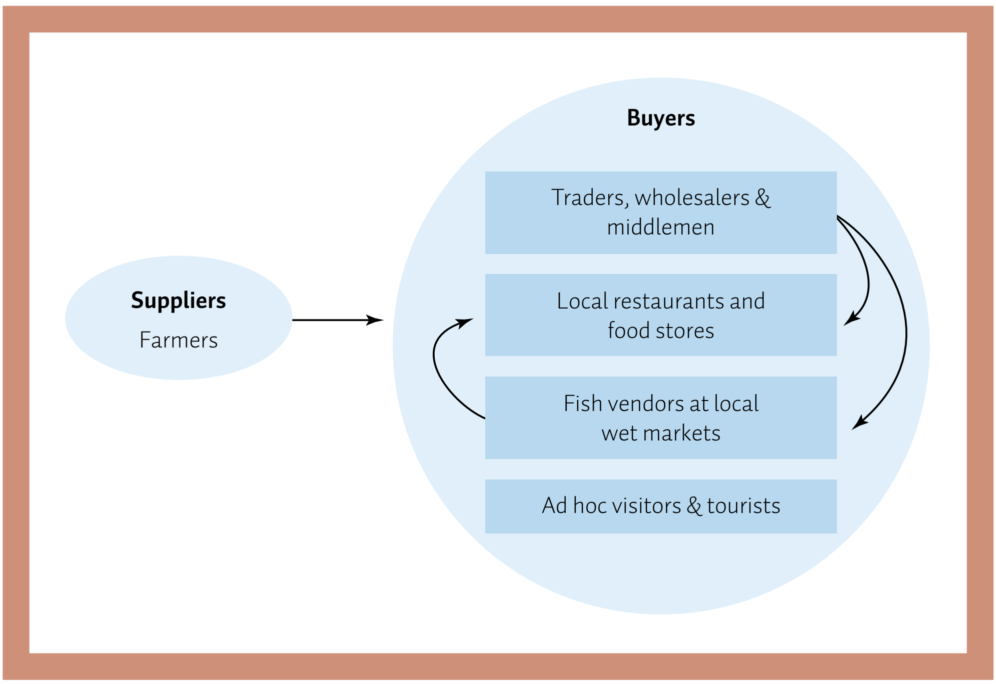

Figure 29. Market chain flow chart

Problems encountered in marketing rural culture-based fishery products

Farmers of rural culture-based fisheries are likely to encounter problems selling their products, which will often be similar to those of other small-scale agricultural practices. The uniqueness of culture-based fisheries is its harvesting pattern, which may lead to market problems. For example, in a culture-based fishery conducted in a non-perennial water body, harvesting can only be done during the dry season when the water level is low. Harvesting is conducted once and the production per hectare may range from 200 kg up to more than 2000 kg. The smallest culture-based fishery may cover four hectares of water surface area. Therefore, a single harvest could flood a limited market. This is a major concern for limited local markets and gaining access to outside markets is often crucial.

The products of rural culture-based fisheries are exclusively fish and prawns. Culture-based fisheries are mostly polycultures of various fish species, and possibly prawns and almost no feeding is carried out during the holding period. Consequently, irregularity in size (i.e. inability to supply a uniform product) can also create a marketing problem.

Most species of cultured fish feed lower in the food chain, and tend to be mostly relatively low value species, thus the primary target market is local consumers. Therefore, the marketability of these products is limited.

Rural fisheries production areas are usually not equipped with good refrigeration systems; some rural areas may not even have access to ice for keeping the harvested fishery products chilled and fresh. Although traders or wholesalers are likely to be equipped with refrigeration systems or ice when they come to collect the produce, the problem is more associated with the farmers. They have to harvest the fish before the traders and wholesalers arrive onsite. During that period, the harvested products might be exposed to heat and deteriorate in quality, resulting in a price deduction or product rejection.

Potential strategies to overcome market problems

Most rural culture-based fisheries are focused on fish only. Diversifying to include some high priced species of either fish or prawns will be a good strategy to increase access to markets other than local consumers. The giant freshwater prawn (*Macrobrachium rosenbergii*), for example, is a relatively high-priced aquatic commodity, which is consumed widely in restaurants and households.

Diversification of product lines to create different end-products for various markets would be an alternative option to the sale of fresh products. It is especially important if there are excessive supplies of freshly harvested fish in the markets. In addition to being sold fresh, fish products can be sold dried, salted and smoked. These fish products generally require some processing, creating a higher return (price) for the farmers. Processing also increases shelf-life allowing greater access to more potential markets. However, the potential of suitable processing techniques, in particular for cyprinid species commonly used in culture-based fisheries, need to be explored.

Security

Fish cultured in natural or artificial water bodies can be affected by natural disasters and human activities. Hence, preparation to deal with unpredictable circumstances is required when working with these natural or quasi-natural systems. To protect final production and the sustainability of culture-based fisheries, producers require four types of security for their crops:

- Protection from unpredictable circumstances/natural hazards, such as floods;
- Protection from human interference, such as poaching;
- Protection from predatory animals, including piscivorous birds, carnivorous fish and mammals; and
- Market security.

Protection from unpredictable circumstances

Natural hazards are unpredictable and can completely destroy a culture-based fishery. Heavy rains in particular can generate floods causing reservoirs to over flow, which can enable the stocked fingerlings to escape. Culture-based fisheries managers can take some precautions to prevent losses from flooding. Fingerlings should be stocked after heavy rains and outlet canals should be covered using small-sized nets. Also, farmers can keep fingerlings in net cages in the reservoir to avoid escape during flood conditions.

Drought periods are also a natural hazard that can affect culture-based fisheries. Water bodies in dry areas, which receive water mainly from monsoonal rains, are more susceptible to unpredictable drought periods. Indigenous knowledge can play a vital role in this context. Rural farmers predict drought periods using environmental clues and such experiences can be used for making preliminary predictions.

Crop insurance can play an important role in natural disasters. Introduction of crop insurance will encourage fish farmers. Crop insurance is available for agricultural crops in Sri Lanka and comparable insurance policies can be developed for culture-based fisheries.

Protection from poaching

Poaching is a big problem in culture-based fisheries. Before a culture-based fishery commences, community members have the right to catch fish in a water body as it is an open access resource. Thus, poaching starts due to the enforcement of new controls on this resource. Once access is denied, people in the community who are not included in the fishery activities may start poaching. Illegal fishing creates severe social conflicts in the community and it can be harmful to the development and sustainability of culture-based fishery practices.

At the preliminary stage, community members should have the ability to select the best group for involvement in the fishery. Proper, community-endorsed selection of fishing groups is the best precaution to prevent or minimise poaching. Community leaders of the village can counsel poachers, or potential poachers can be included as members of the fishing group.

As poaching intensifies during harvesting, the farmers need to guard the water body, especially at night. Farmers construct watch-houses in trees around the water body to guard it (Figure 30) and take turn to watch. Each member has the responsibility to prevent illegal fishing. Fishing in the water body is prohibited to control fishing by outsiders as well as members of the fishing organisation. In some water bodies, netting is completely prohibited and angling is allowed. In Sri Lanka under the Agrarian Services Act, fishery practices are defined as an agricultural practice which gives legal coverage for the fishing group.

Under the licensing systems introduced by the National Aquatic Development Authority of Sri Lanka, farmer organisations have the right to take legal action against poachers. However, on most occasions the government extension officers and community leaders are able to resolve such conflicts. Legal action against poachers creates cracks in social groups. It will be more successful to form a committee that includes community leaders, village level administrative officers, religious leaders and aquaculture extension officers. Figure 31 shows the possible prevention strategies at village level.

Protection from predatory animals

Predatory animals can severely reduce total fish yields. Thus, as mentioned in section 1.3.4.a, stocked fish need to be protected against common predatory species such as snakeheads, walking catfish, climbing perch, goby species, eels and sting catfish.

Figure 30. Watch-house.

Market security

Market security for the final product is extremely important for profit maximisation. For example, good quality, shelf-size fish commands a higher demand. Selection of species for culture-based fisheries should also take market preferences into account. Research in Sri Lanka indicates that bighead carp is in demand in the northern part of the island, but less so in the south. As area-based consumer preferences may also be prevalent in other nations, careful planning and market research is required on the potential species to be cultivated in each area.

As indicated above, in most countries, culture-based fisheries tend be harvested within a short period, particularly when the water level recedes which is often dictated by climatic factors. Accordingly, there is greater possibility that within a small area there could be an oversupply of fish in a narrow time frame. Staggered harvesting, over a period of two to three weeks, towards the end of the culture cycle as the water levels begin to recede, ensures market security for culture-based fishery products and prevents overloading market supply during harvesting seasons. Filleted freshwater fish have good market

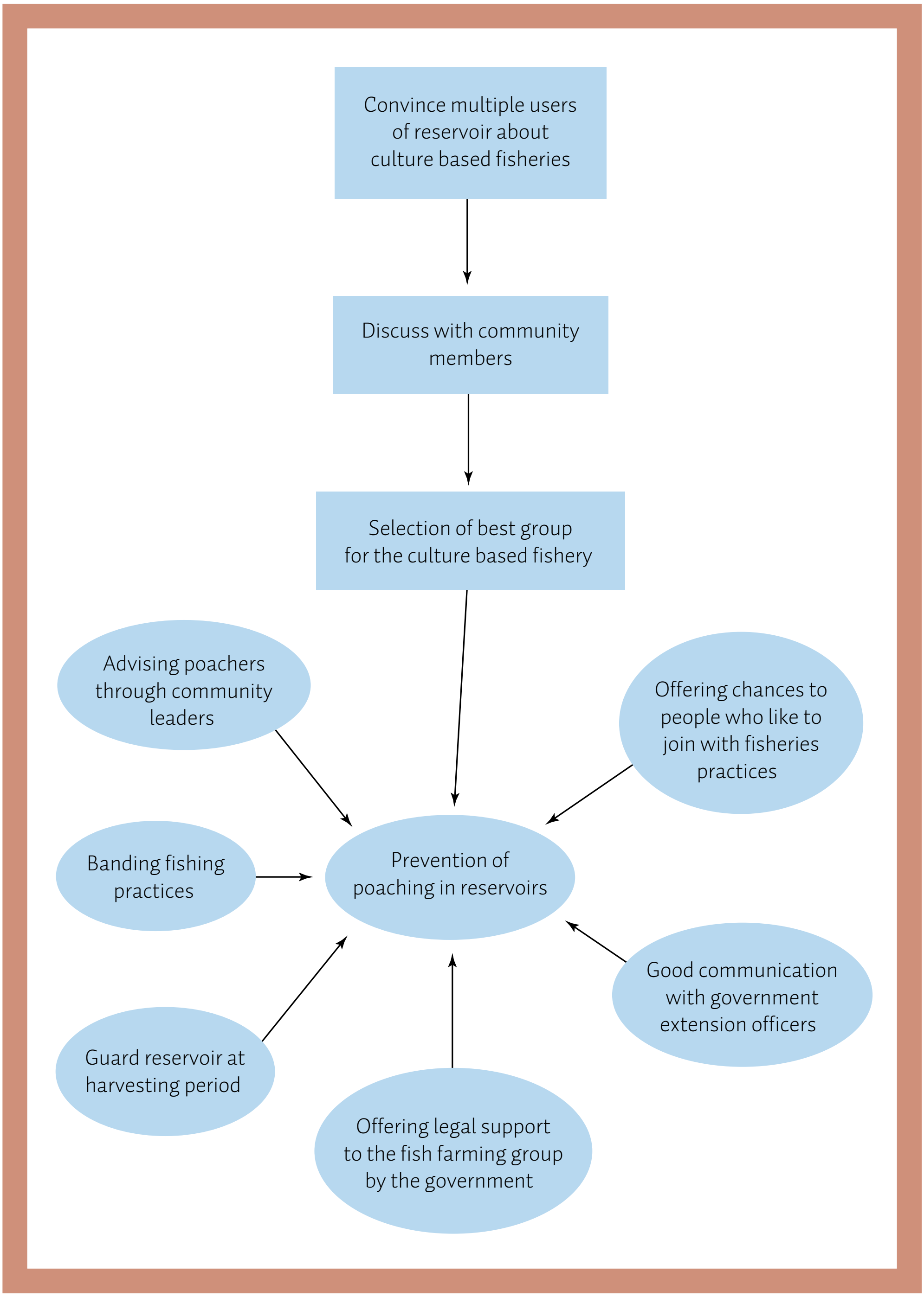

Figure 31. Schematic diagram showing the present strategies practiced to minimise poaching in culture-based fisheries of Sri Lanka.

demand and customers like to pay extra for value added products. Supply for processing can be insufficient, but combinations of groups of farmers have the potential to initiate value added production.

Constraints and future prospects

Culture-based fisheries are not entirely new. Some people recognised their importance and potential as long ago as the early 1960s. However, it did not gain much impetus until recently. In the early 1970s, the general emphasis was on the development of conventional aquaculture practices. Consequently, resources were channelled in this direction, the foremost of such resources being seed stock. The subsequent technical developments associated with artificial propagation of most of the popularly cultured species reduced constraints on seed stock supplies; as such, a primary bottle-neck in respect of culture-based fisheries development was lessened. Culture-based fisheries have gained momentum in most developing countries in Asia due to these technological developments, together with the realisation that primary resources, such as water, for fish production should be a secondary use only, and that these developments are less resource intensive.

However, culture-based developments are not without technical and socio-economical constraints. The constraints may be of a general nature or be specific to regions/nations. Seed supply is one of the most general constraints. As culture-based fisheries often depend on the hydrological cycle, suitably sized seed stock of the preferred species should be available, in sufficient quantities, within the narrow time frame of when the water bodies fill.

The harvesting period is also related to the hydrological cycle. Harvesting often has to be carried out as the water level recedes. This can pose two problems: firstly, the availability of labour (experienced) and gear may be limited within a given area; and secondly, many water bodies may have to be harvested within a very narrow time frame, resulting in a glut of fish and reducing farm gate prices. As suggested above, the latter constraint could be overcome to a significant degree by staggering harvesting.

Conflicts amongst water users may not be uncommon, and could become a major constraint. However, such constraints can be minimised by initial communal consultations.

As evident previously, very often culture-based fisheries are undertaken by farming communities who have limited or very little experience in fishery practices. Therefore, it is imperative that such communities are provided with sufficient knowledge prior to developing a culture-based fishery. They also require close monitoring for a few years until sufficient expertise is gained and confidence is developed. These constraints are best minimised by providing an effective extension service. Effective extension services can be provided only if the relevant institutional mechanisms are available and often such provision is related to governmental policy. It is heartening that some nations in the region have accepted culture-based fisheries development as governmental policy. It is expected that appropriate institutional structures for effective implementation of these policies will be implemented.

Throughout this manual it has been emphasised that culture-based fisheries are ideally conducted in small water bodies, which are incapable of supporting a fishery from natural recruitment. It has been estimated by the FAO (1999) that there are nearly 62 million hectares of small water bodies in the region. However, for the reasons discussed in previous sections, not all of these will be suitable for culture-based fisheries development. Even if all these were suitable, it would be an impossible task to find sufficient seed stock for developing culture-based fisheries in all of these water bodies.

De Silva (2003) estimated that if only 5% of these available water bodies are harnessed for culture-based fisheries, and that the practices are developed to the extent that an average yield of 750 kg/ha is obtained (which is not an improbability), rural fish production in Asia could be increased by 2.5 million tons per year. Therefore, culture-based fisheries have the great potential to increase the supply of fish (as food) in the region.

Very often, small water bodies in the region are located in rural areas. An increase in fish food supplies will therefore benefit mostly rural communities and contribute to alleviating their poverty. However, in order to gain the maximum benefits from culture-based fisheries, the constraints mentioned previously need to be minimised and activities have to be coordinated in such that all participating communities benefit to a similar degree.

Sustainability

Sustainability of culture-based fisheries in tropical Asia depends on technical and socio-economic feasibility with the selection of suitable water bodies being a key to success. The suitability of a water body for culture-based fisheries development depends on a number of features or characteristics.

The water retention period of the water body (8–9 months is optimum for fish reaching marketable sizes) and depth of water of the effective area (2.0–2.5 m is optimal) are important basic characteristics to be considered. Productivity that can be roughly determined based on the colour of the water (green water is productive; brownish clear water is less productive), and on the availability of additional sources of nutrients, such as cattle grazing. Also, water bodies located near villages are more suitable because of a better capability to prevent poaching, and better accessibility to markets. Presence of water weeds (more than 75% plant cover would make a water body unsuitable) and water pollution levels are also important factors to be considered in the selection of water bodies.

Social mobilisation is an important aspect for achieving sustainable culture-based fisheries. Various social taboos and beliefs are known to influence decision-making processes in culture-based fisheries. Influences of some religious groups cannot be neglected. However, through community participatory approaches such as exploratory rural appraisal (ERA) and participatory rural appraisal (PRA) methodologies, it is possible to mobilise rural communities to adopt culture-based fisheries practices.

A preliminary financial assessment of a proposed culture-based fishery is useful to demonstrate the potential economic and other benefits from the activity. Such an analysis will have considerable influence on the community members' attitude towards fish farming and, therefore, the degree of participation.

Community perceptions on ownership of the water body and any competition among user groups are also important aspects to be considered when selecting suitable water bodies for culture-based fisheries. As government agencies usually lack the financial and human resources to fulfil this requirement, it is important to use existing local structures and stakeholders to support extension officers with the planning, assessment, and implementation of the fish farming program.

Considerable degrees of risks and uncertainties are involved at virtually every stage of developing a culture-based fishery ranging from production of seed in hatcheries and stocking to harvesting and marketing. Success in the induced breeding of the major carps is dependent on the nutrition of parent fish, water quality and rainfall patterns. During the fingerling rearing stage, various factors such as predation, mortality due to water pollution, and escape of fish from the culture systems, may bring about financial losses to the farmers. Difficulty to find a market outlet for the fingerlings, due to unfavourable weather conditions for rearing fish, may also be a major concern of fingerling rearers. Since culture-based fisheries are a form of extensive aquaculture, there is no significant intervention by fish farmers to maintain high survival rates after stocking in the water body. All these factors bring about financial uncertainties for the persons who are involved in culture-based fisheries. As such, it is natural that some villagers are reluctant to invest money in culture-based fisheries. In order to provide fish farmers with an assurance for preventing the threat of financial losses, an insurance scheme, as practiced in the agricultural sector (i.e., crop insurance), can be introduced. This kind of scheme is useful for achieving sustainable culture-based fisheries.

As the sustainability of culture-based fisheries involves many crucial stages, to make this strategy successful it is necessary to establish high profit margins for all outputs associated with the overall process. As can be seen from Figure 32, high financial risks are associated with induced production of post-larvae, fry rearing and fingerling rearing. The financial risk is comparatively low at the level of rearing of fingerlings to marketable size as a form of extensive aquaculture. In other words, higher economic gains are associated with Level IV compared to other levels. As such, financial adjustments should be made to ensure reasonable gains at the lower levels of the aquaculture strategy. This can be achieved by setting reasonable 'control prices' for post-larvae, fry and fingerlings. This is practically feasible because the profit margin of Level IV is much higher than at the other levels.

Usually culture-based fishery practices in a given water body consist of one culture cycle per year because the fish species suitable for stocking (i.e., Chinese and Indian major carps) require 7–9 months to grow to marketable size. In the case of non-perennial reservoirs of Sri Lanka, climatic factors determine the growth cycle because the water retention period is essentially 7–9 months each year. However, induced breeding in hatcheries can be performed several times per year with two peak spawning periods during monsoonal rainy seasons. As such, post-larval, fry and fingerling rearing are basically carried out almost year-round. As demand for fingerlings for culture-based fisheries usually

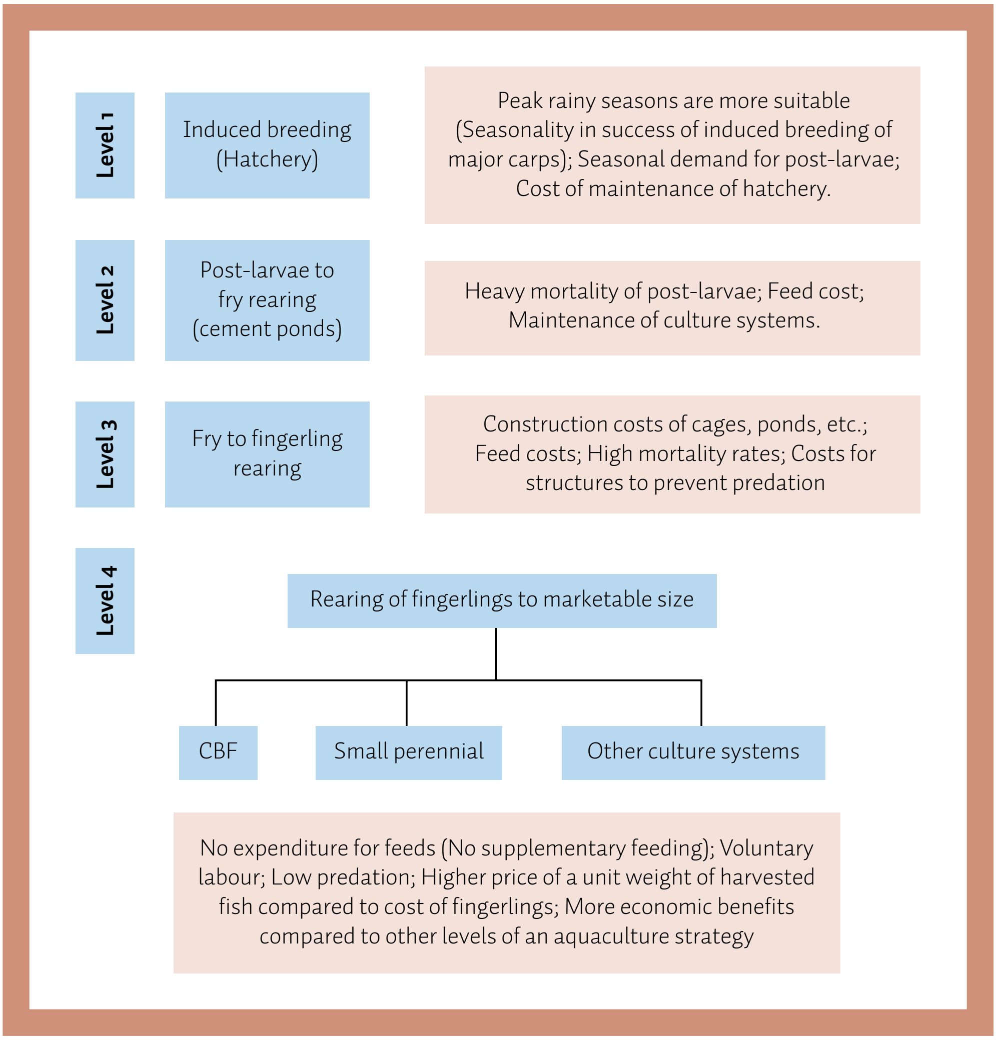

Figure 32. Financial risks (red boxes) at different stages/ levels of inputs that are expected to lead to a successful culture-based fishery.

occurs once per year, it is necessary to find alternative market outlets for fingerlings. Hence, clustering of several culture systems (e.g. culture-based systems, small perennial reservoirs, pond culture systems and cage and pen culture systems) with the facilities for rearing post-larvae, fry and fingerlings will ensure continuous demand for fingerlings and facilitate sustainability.

As mentioned in previous sections, staggered harvesting is an efficient mechanism for harvesting, selling of harvested fish and preventing flooding the market in order to assure the sustainability of culture-based fisheries strategies.

PART TWO

CASE STUDIES

Culture-based fisheries development in Sri Lanka: a case study

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Introduction

Reservoir resources

In Sri Lanka, reservoir construction was an integral part of ancient civilisation and some of the major reservoirs (>800 ha) are over 2000 years old. (Many landmarks still remain proving the sovereignty of hydraulic civilisation of Sri Lanka, which runs throughout more than 2500 years of country's written history (Brohier 1934, 1937)). The total extent of reservoirs of Sri Lanka is about 170,000 ha (Costa and De Silva 1995). When the total area of the island (65,000 km2) is considered there are approximately 2.6 ha of reservoirs to every square kilometre of the island. This is perhaps the highest density of reservoirs in the world. Sri Lanka is also blessed with 103 perennial rivers; the river basins cover approximately 90% of the land area (NARESA 1991).

Reservoirs of Sri Lanka are of two types: perennial, large reservoirs; and non-perennial, small reservoirs, often less than 20 ha at full supply level (FSL), (these are referred to locally as seasonal tanks) (Table 2). There are

Table 2. Different types of reservoirs and their cumulative extents (adopted from: Costa and De Silva 1995).

Reservoir category	Number	Extent (ha)	Per cent
Major irrigation reservoirs (ancient)	73	70,850	41.7
Medium scale reservoirs (ancient)	160	17,001	10.0
Minor irrigation reservoirs (ancient)	>10,000	39,271	23.1
Floodplain lakes (natural)		4,049	2.4
Upland hydroelectric reservoirs (recent)	7	8,097	4.7
Mahaweli multipurpose system of reservoirs (recent); Victoria, Kotmale, Randenigala, Ulhitiya-Rathkinda		13,650	8.0
Other		17,023	10.0
Total		169,941	100.0

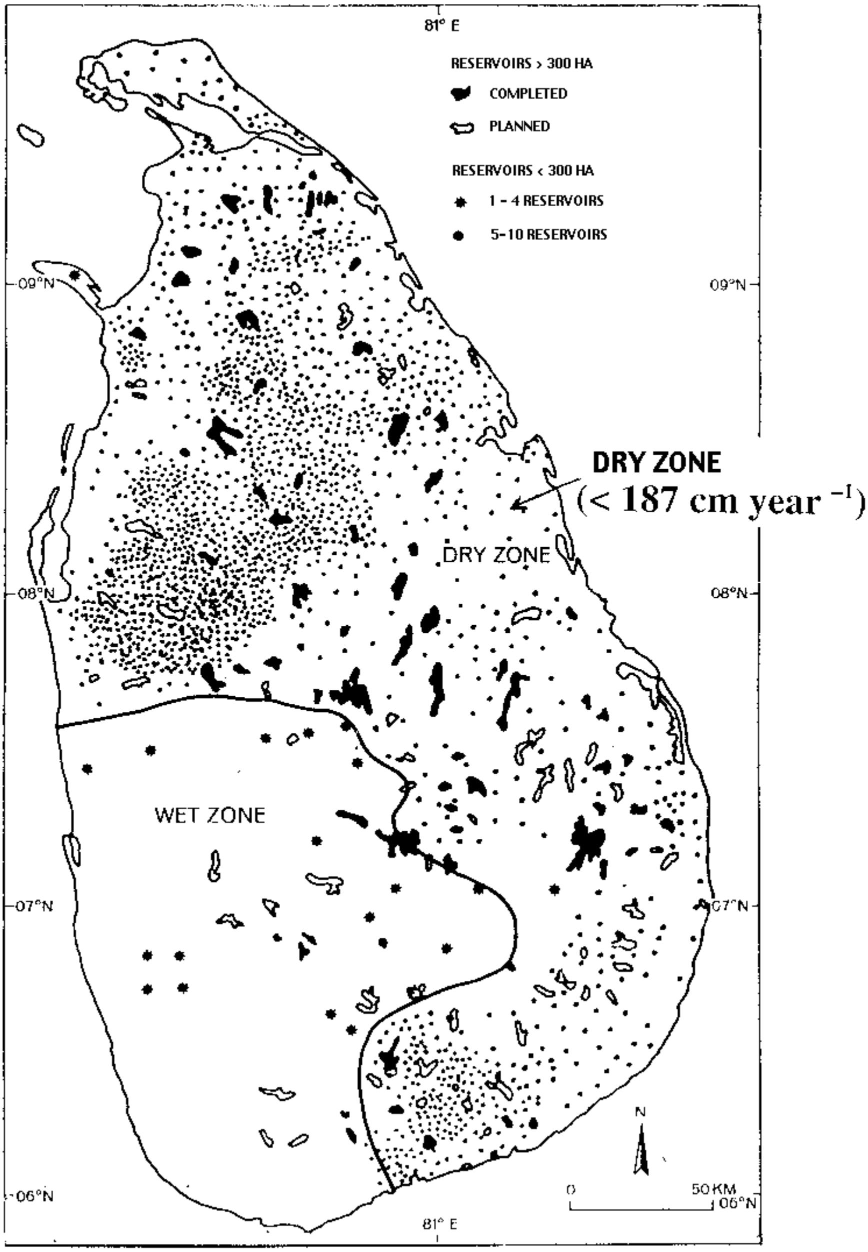

Figure 33. Reservoirs of Sri Lanka (adopted from: Fernando 1993).

no established commercial fisheries in these non-perennial water bodies as opposed to large (>200 ha) perennial reservoirs, where the fisheries are based mainly on naturally recruiting populations of exotic cichlids (De Silva 1988; Amarasinghe 1998). The Department of Agrarian Services (Anon 2000) estimates there are over 12,000 small reservoirs in Sri Lanka (Table 3) most of which are located in the dry zone of the country (Figure 33). Panabokke (2001) stated that these small village reservoirs, which are distributed across the undulating landscape of the dry zone, are not randomly located. They occur in the form of distinct cascades that are positioned within well-defined small watersheds or meso-catchment basins. Mendis (1977) estimated the total extent of small village reservoirs of Sri Lanka as about 39,300 ha.

Most of these small village reservoirs are non-perennial reservoirs. They usually dry up completely during July–September and fill during the inter-monsoonal rains in December–January. The non-perennial reservoirs of Sri Lanka are highly productive, mainly because of the change in environmental conditions from a terrestrial phase during the dry season to an aquatic phase during the wet months. Residues of terrestrial vegetation form a major organic input into these reservoirs. In some reservoirs, which do not dry up completely, small puddles may be left during the dry months. Therefore, some indigenous carnivorous fish species, such as snakeheads (*Channa* sp.), climbing perch (*Anabas testudinaeus*) and catfishes (*Macrones* sp.), with suitable respiratory organs can survive in the reservoirs during the dry season.

Historical aspects of CBF developments in Sri Lanka

Mendis (1965) was the first in Sri Lanka to show that these water bodies could be utilised for the development of culture-based fisheries. As a follow-up of these recommendations, attempts were made in 1960s to utilise non-perennial reservoirs for the development of culture-based fisheries (Indrasena 1965). In the 1960s, some reservoirs were stocked with Mozambique tilapia *Oreochromis mossambicus* fingerlings of 7.5–10.0 cm and during 8–9 months of the water retention period, they reached 25–30 cm in size (Indrasena 1965). Fernando and Ellepola (1969) reported that in February–March 1963, eight small reservoirs in the north–central province of Sri Lanka were stocked with milk fish (*Chanos chanos*) and *O. mossambicus*, which were harvested in September 1963. They also reported their observations collected in Dalukanawewa during fishing season in July–August 1964. Fish harvests from three of these reservoirs, as estimated from the values indicated by Fernando and Ellepola (1969), are given in Table 4. Mendis (1977) estimated that the production potential for culture-based fisheries in small village reservoirs would be 13,000 tonnes on the basis of a mean fish yield of 330 kg/ha/ yr.

Local scientists have clearly shown that the development of culture-based fisheries in non-perennial reservoirs of Sri Lanka is an effective means for increasing inland fish supply. However, this strategy was not incorporated in national fisheries development plans until Rosenthal (1979) and Oglesby (1981), who served as consultants under a project funded by FAO in 1979–1980, made recommendations on the basis of research findings of local scientists in the 1960s. A program was subsequently implemented to formulate a suitable

Table 3. Distribution of small reservoirs in the administrative districts of Sri Lanka (Source: Anon 2000).

District	Number of reservoirs		
	Functioning	Abandoned	Total
Ampara	181	87	268
Anuradhapura	2333	665	2998
Badulla	259	128	347
Batticaloa	132	110	242
Colombo	3	2	5
Galle	0	0	0
Gampaha	24	33	57
Hambantota	446	23	469
Kalutara	6	1	7
Kandy	47	11	58
Kegalle	7	3	10
Kurunegala	4192	77	4269
Mannar	61	51	112
Matale	278	33	311
Matara	24	3	27
Moneragala	285	151	436
Nuwara Eliya	54	17	71
Polonnaruwa	79	36	115
Puttalam	743	175	918
Ratnapura	59	8	67
Trincomalee	428	196	624
Vavunia	453	101	554
Total	10094	1911	12005

Table 4. Fish harvests from three seasonal reservoirs in the north–central province of Sri Lanka in the early 1960s. *Oreochromis mossambicus* comprised practically the whole catch (Source: Fernando and Ellepola 1969). Effective area of a seasonal reservoir is considered as 50% of the extent at full supply level (FSL). The fish yield is estimated for the effective area of each reservoir.

Reservoir	Culture period	Extent at FSL (ha)	Effective area (ha)	Total yield (kg)	Yield (kg/ ha/yr)
Timbirigaswewa	1963	12	6	1587	264.5
Moragaswewa	1963	41	20.5	3175	154.9
Dalukanawewa	1963	12	6	1587	264.5
Dalukanawewa	1964	12	6	2268	378.0

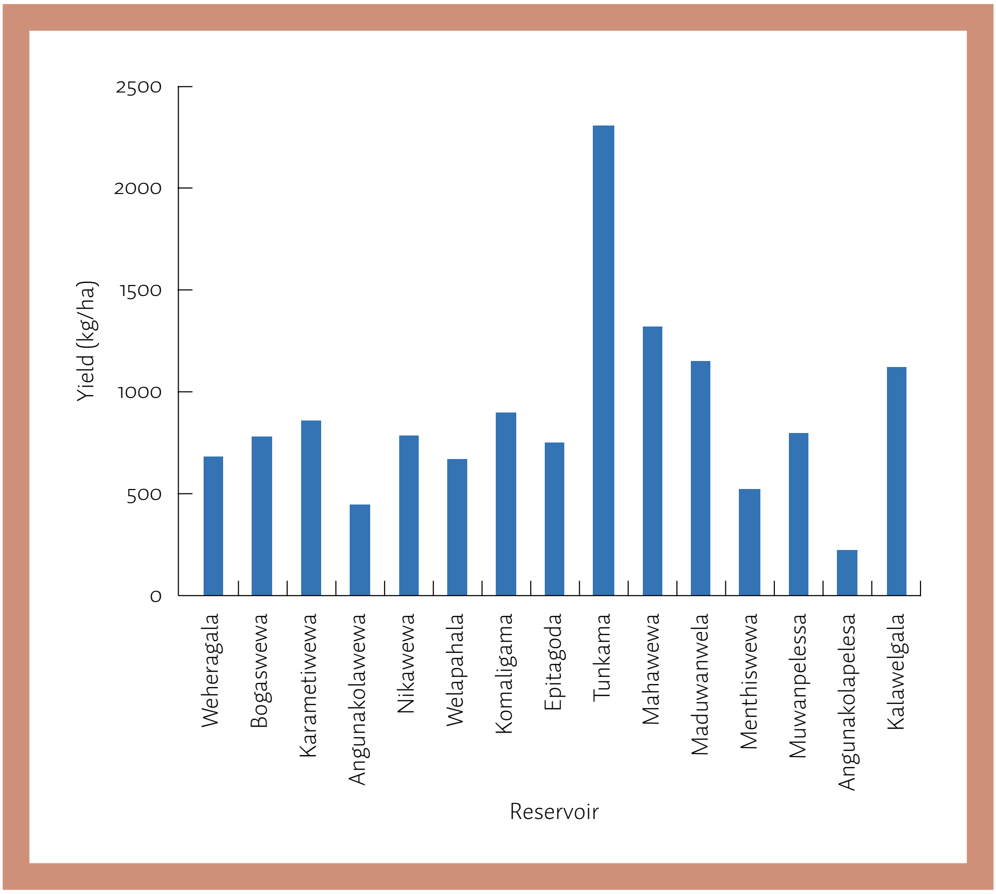

Figure 34. Fish yields within a single culture cycle (1983–1984) in 15 seasonal reservoirs. (Modified from: Chandrasoma and Kumarasiri 1986).

Table 5. Some details of the fish yields over four growing seasons in four seasonal reservoirs (Adopted from: De Silva 1988). SD – Stocking density; CP – Culture period; T – Tilapia; GC – Grass carp; BC – Bighead carp; CC – Common carp; HK –Hirikanaya (*Labeo dussumieri*).

Reservoir/ Year	SD (No/ha)	Species (%)					CP (months)	Yield Kg/ha
		T	GC	BC	CC	HK		
Tunkama (4 ha)								
1979/80	6250	12	44	36	8	-	8	1961
1980/81	5410	53	-	19	28	-	8	1154
1981/82	3475	-	-	81	19	-	8	3274
1982/83	1726	Not available					4	215
Thimbirigaswewa (5.7 ha)								
1979/80	9825	50	-	-	50	-	8	195
1980/81	5000	98	-	-	2	-	8	239
1981/82	3684	33	33	33	-	-	7	18
Maduwanwela (2.5 ha)								
1980/81	3780	86	-	11	3	-	8	775
1981/82	2214	-	-	77	-	23	10	424
1982/83	2129	40	27	13	20	-	8	1676
Kudahatawewa (7 ha)								
1979/80	9143	50	-	-	50	-	8	719
1980/81	4615	100	-	-	-	-	8	841
1981/82	3000	33	33	33	-	-	7	70

strategy for the development of culture-based fisheries in non-perennial reservoirs of Sri Lanka (Thayaparan 1982).

For some non-perennial reservoirs, Chakrabarty and Samaranayake (1983) reported fish yields, mean survival rates and mean weight at harvesting of the stocked species. These estimates indicate that fish yields in a culture cycle varied considerably from 18 kg/ha to 1961 kg/ha (Table 5). The highest survival was reported for *O. mossambicus* whereas fast growth rates were observed for -common carp, grass carp and bighead carp (Table 6). This experimental project was funded by FAO/UNDP (FAO/UNDP 1980). The Asian Development Bank also subsequently financed a project on aquaculture development in Sri Lanka. The main objective was to utilise small village reservoirs for culture-based fisheries development. This project commenced in 1984 and involved the strengthening of six fish breeding centres and eight fingerling-rearing centres, which were owned by the Ministry of Fisheries (Thayaparan 1982).

Table 6. Mean survival rates, mean weights at harvesting and yields of stocked species in seasonal reservoirs in 1979/80, 1980/81 and 1981/82. Ranges are given in parentheses.

Species	% Survival	Mean weight (kg)	Yield (kg ha-1)
Bighead carp	57.0 (5.0–87.3)	1.14 (0.31–2.05)	527 (62–1525)
Common carp	26.9 (0.37–50.0)	1.29 (0.46–4.55)	79 (4.2–315)
Grass carp	28.3 (0.15–30.0)	1.24 (0.3–5.4)	165 (6–764)
Mozambique tilapia	91.8 (79.7–100)	0.15 (0.10–0.18)	503 (412–841)
Hirikanaya	10.9 (3.9–23.3)	0.60 (0.10–1.70)	503 (9–1952)
Nile tilapia	45.8 (10.6–85.7)	0.39 (0.33–0.45)	353 (25–1541)

Chandrasoma and Kumarasiri (1986) reported the results of culture-based fishery trials in 15 non-perennial reservoirs, carried out in the 1980s with rural community participation. Fingerlings of common carp, Chinese and Indian major carps of 5–8 cm size, produced in the fish breeding stations, were stocked in the reservoirs. At the end of the culture period of 7–10 months, fish were harvested by the rural farmers using encircling nets. Fish yields ranged from 220 to 2300 kg/ha (mean 892 kg/ha) within a single growing season (Chandrasoma and Kumarasiri 1986).

However, these culture-based fishery practices were not sustainable. De Silva (1988; 2003) discussed in detail the likely reasons for the overall failure of the strategy. In addition to the reasons associated with socio-economic and marketing aspects and technological reasons associated with the lack of a guaranteed fingerling supply, unavailability of usable models for selecting suitable water bodies was considered to be one of the major constraints that impeded the development of culture-based fisheries.

Calendar for culture-based fisheries in non-perennial reservoirs of Sri Lanka

Culture-based fisheries in Sri Lanka are essentially developed in non-perennial reservoirs. These reservoirs fill with water only after the inter-monsoonal rains in November–January every year. The water retention period in non-perennial reservoirs is 7–9 months. As such, these reservoirs should be stocked with fish fingerlings in January–February. Accordingly, fingerling rearing, fry rearing and induced breeding of fish should be done at a time so that fish fingerlings are available in January–February (Figure 35).

Institutional coordination in culture-based fisheries

Although culture-based fishery practices were initiated in the 1980s, they were not sustainable. Consequently some positive policy decisions were made in parallel with field level development strategies. The most important policy change was an improvement in the liaison between the Department of Agrarian Services and the Ministry of Fisheries, in order to develop culture-based fisheries in non-perennial reservoirs.

Month	Inputs & outputs		
May	Induced breeding of major carps		
June			
July	Fry rearing		
August			
September	Fingerling rearing		
October			
November			
December	Rainy season	Stocking	
January			
February			
March			
April			
May			Culture period
June			
July			
August			
September			
October		Harvesting	
November			

Figure 35. Correct timing of culture-based fisheries in seasonal reservoirs of Sri Lanka (Modified from: De Silva 1988).

All non-perennial reservoirs and small irrigation reservoirs come under the jurisdiction of the Agrarian Services Department, which established a village farmers' organisation for each reservoir. These organisations are responsible for day-to-day water management. The revision of the Agrarian Development Act in 2000 to make provisions for community participation in aquaculture in non-perennial reservoirs, culture-based fishery practices has enabled coordination at decision-making levels between the fisheries and agrarian sectors

For most seasonal reservoirs, farmers' organisations have set up aquaculture committees. These committees are responsible for the management of culture-based fisheries. A proportion of the profit from the culture-based fisheries is utilised for making improvements to the reservoir, for example strengthening the earthen bunds. Thus, there is a strong relationship between the aquaculture committee and the farmers' organisation. Under the revised Agrarian Development Act No. 46 of 2000, these institutional arrangements have been legally strengthened and provisions were made for the development of capture and culture-based fisheries. Accordingly, a well-structured institutional link has been developed between the National Aquaculture Development Authority of Sri Lanka and the Department of Agrarian Services through which the field-level coordination is largely facilitated (Figure 36).

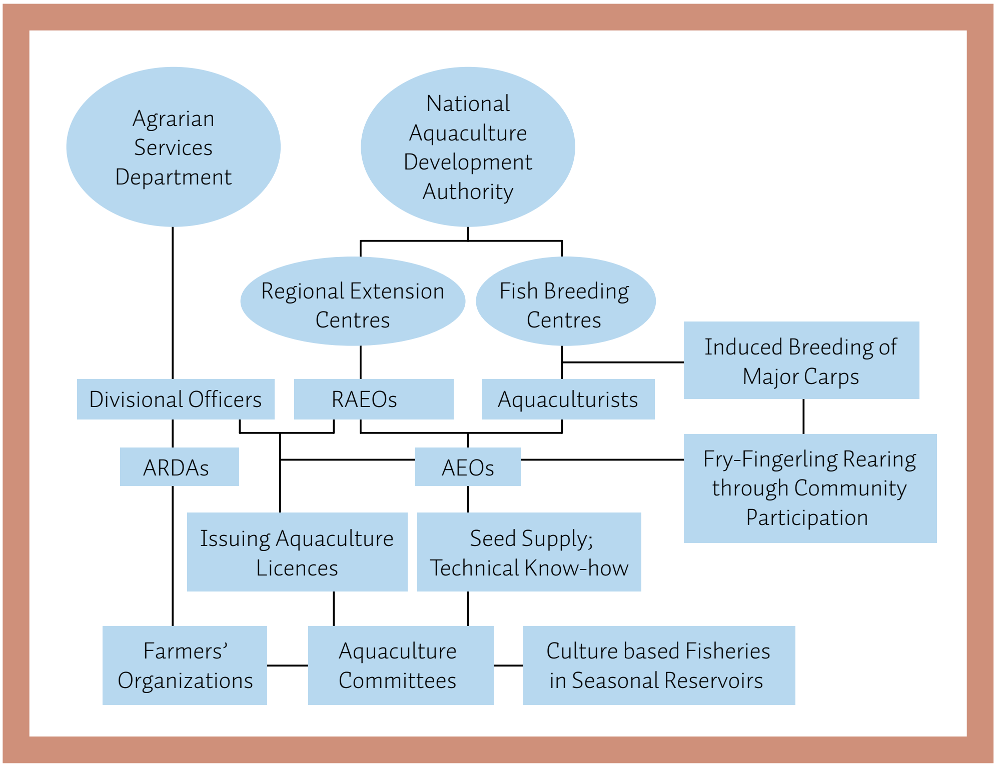

Figure 36. Institutional links between the culture-based fisheries in seasonal reservoirs of Sri Lanka (AEO – Aquaculture Extension Officer; RAEOs – Rural Extension Officers, ARDAs – Agricultural Development Authorities).

Reservoir bed preparation for culture-based fisheries

Reservoir beds need to be prepared in most seasonal reservoirs prior to stocking. Removal of impediments to fishing such as submerged and decaying three stumps, aquatic macrophytes etc, is necessary in order to facilitate the use of seine nets for harvesting stocked fish. Members of the aquaculture committee are actively involved in these labour-intensive practices. In some reservoirs, farmers do not remove macrophytes until the onset of harvesting because their presence prevents poaching.

Species cultured

As the culture period in non-perennial reservoirs is 7–9 months, the species suitable for stocking in reservoirs need to reach a marketable size in 6–8 months. These species should also be able to utilise the natural food resources available in the reservoirs. Among the Sri Lankan indigenous fish fauna, such species are not available. Exotic tilapias are not desirable because they tend to mature early in life in small water bodies. As such, culture-based fisheries in seasonal reservoirs rely exclusively on common carp, and the Chinese and Indian major carps. These species are artificially spawned successfully in state-owned hatcheries in Sri Lanka (Weerakoon 1979; Balasuriya et al. 1983).

As the food habits of different species of the Chinese and Indian major carps and common carp have little overlap, it is possible to culture several species occupying various food niches in the reservoir ecosystem. This system is known as polyculture. In non-perennial reservoirs of Sri Lanka, where culture-based fisheries occur, fingerlings are stocked approximately in equal proportions of bighead carp, rohu, catla and common carp. Grass carp and mrigal are also cultivated but they are used in low proportions (about 5% of all species).

The area of non-perennial reservoirs shrinks with time from being full during the rainy season to almost empty during dry season. As such, it is necessary to use 50% of the reservoir area at its full supply level as the effective area. A reliable estimate of reservoir area is essential to determine the stocking density. Stocking density (SD) and culture-based fishery yields are related according to a second order polynomial curve with the optimal SD of 2400 fingerlings per hectare (Figure 37).

Remote sensing and culture-based fisheries in Sri Lanka

Remote sensing is an effective technique for planning culture-based fisheries in non-perennial reservoirs of Sri Lanka. As it is important to determine accurately the reservoir area at full supply level, the area should be estimated from survey maps prepared from aerial photographs of the area. These areas are generally lower than the actual area because of the non-perennial nature of reservoirs. The reservoir area can also be accurately determined using remote sensing techniques based on the satellite imagery. It has been found that the reservoir areas determined from satellite imagery is in good agreement with the reservoir area estimated from geographical positioning systems (GPS) (Wijenayake et al. 2005a) (Figure 38).

Remote sensing techniques can also be used to determine shoreline length of a reservoir. As the ratio of shoreline length to reservoir area is significantly related to yield (Figure 38) (Jayasinghe et al. in prep.), remote sensing based on satellite imagery has the potential to predict culture-based fishery yields in non-perennial reservoirs of Sri Lanka.

Wijenayake et al. (2005a) have shown that macrophyte cover in perennial reservoirs can be quantified by remote sensing based on satellite imagery. Reservoirs with high macrophyte cover are less productive in terms of chlorophyll-a content and fish yields (Figure 40).

Conditions for success of culture-based fisheries in Sri Lanka

To achieve high yields from culture-based fisheries, it is essential to have fingerlings available, suitable non-perennial reservoirs selected and post-stocking management implemented. However, it is highly unlikely that fingerlings will ever be available in sufficient quantities to stock all non-perennial reservoirs in Sri Lanka. Thus, it is important that wise use of the available seed stock is made through selecting reservoirs that are suitable for developing and sustaining culture-based fisheries.

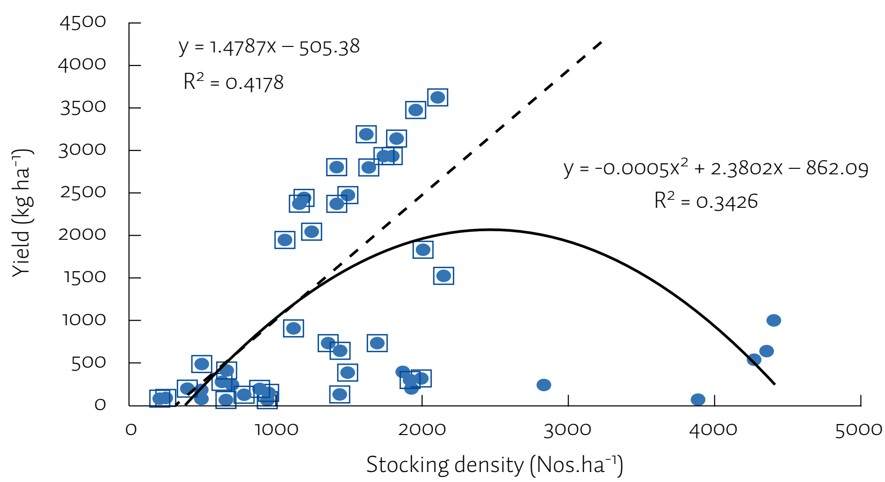

Figure 37. Relationship between fish yield (Y) and stocking density (SD) in non-perennial reservoirs of five administrative districts. The linear relationship (broken line) indicates Y and SD relationship in reservoirs of Hambantota, Ratnapura and Monaragala districts (squares).

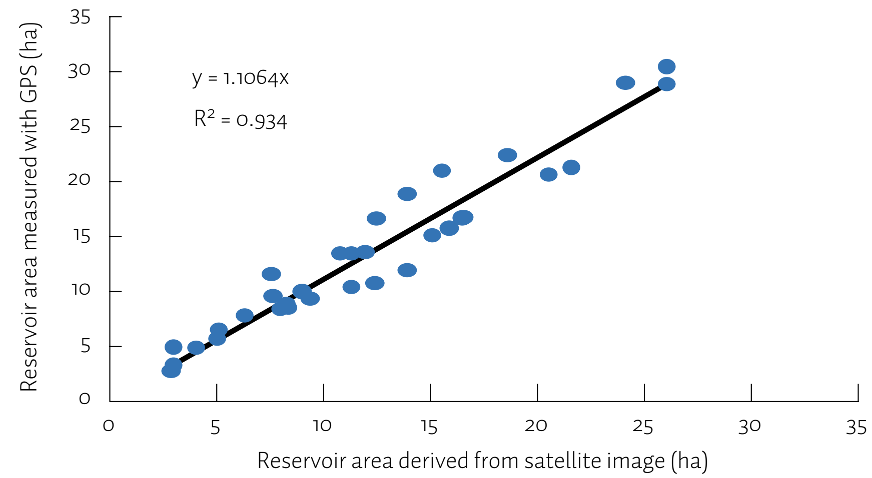

Figure 38. Strong agreement between the actual reservoir area (estimated using GPS) and reservoir area calculated from satellite images. (The regression through origin was fitted) (Source: Wijenayake et al. 2005a).

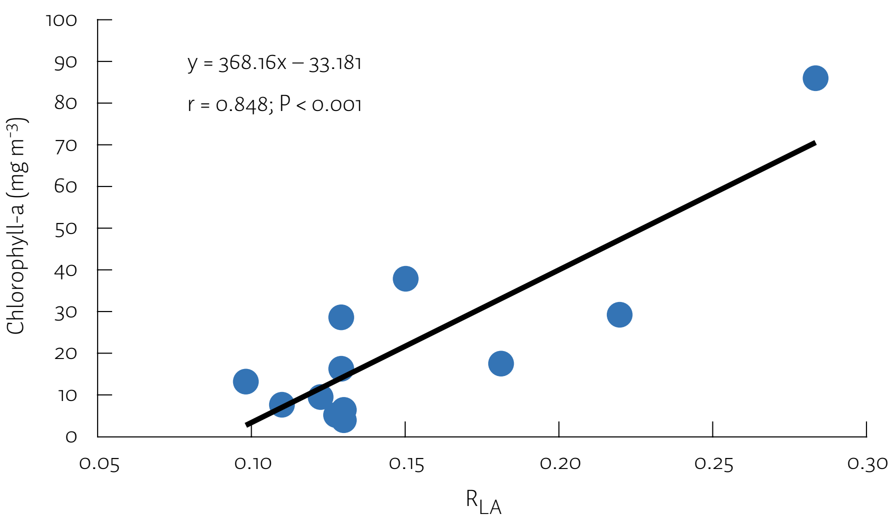

Figure 39. Relationship between shoreline-area ratio (RLA) and chlorophyll-a content of non-perennial reservoirs (Jayasinghe et al. in prep.)

Pushpalatha (2001) reported a case study of rural aquaculture in Sri Lanka for the production of fish fingerlings in ponds and cages. In eight earthen ponds ranging in size from 136 to 540 m2, fry of mrigal- *Cirrhinus mrigala*, common carp- *Cyprinus carpio*, hirikanaya- *Labeo dussumieri* and rohu- *Labeo rohita* were stocked. After a growing period of 62–78 days, survival rates of fingerlings were 33–86% (Table 7) (Pushpalatha 2001). Pushpalatha (2001) also reported that in eight perennial reservoirs, fish fry were reared to fingerling size in net cages of 4 m x 2.5 m x 2 m in size and made of 4 mm mesh nets. With the stocking density of about 5000 fry per cage, high survival rates (55–92%) were achieved within the culture period of 58–80 days (Table 8).

This case study indicates that in Sri Lanka, it is possible to introduce a strategy for rearing fish fry to fingerling size in net cages and earthen ponds. However, low-cost feed for fry rearing, and subsidy schemes to cover the initial costs of cage and pond construction etc, are needed for this strategy to be sustainable. As mentioned above, the fingerlings should be stocked in non-perennial reservoirs just after the heaviest rainy season (November–January) in the dry zone of the country, so timing of production of fingerlings correctly is also necessary for successful implementation of culture based fisheries in seasonal reservoirs (Figure 35). When small sized (5–8 cm) fingerlings were stocked in seasonal reservoirs, heavy mortalities resulted (Amarasinghe 1998). As practised in China (Li 1988), production of bigger fingerlings (10–14 cm) might help to minimise mortality rates of juveniles.

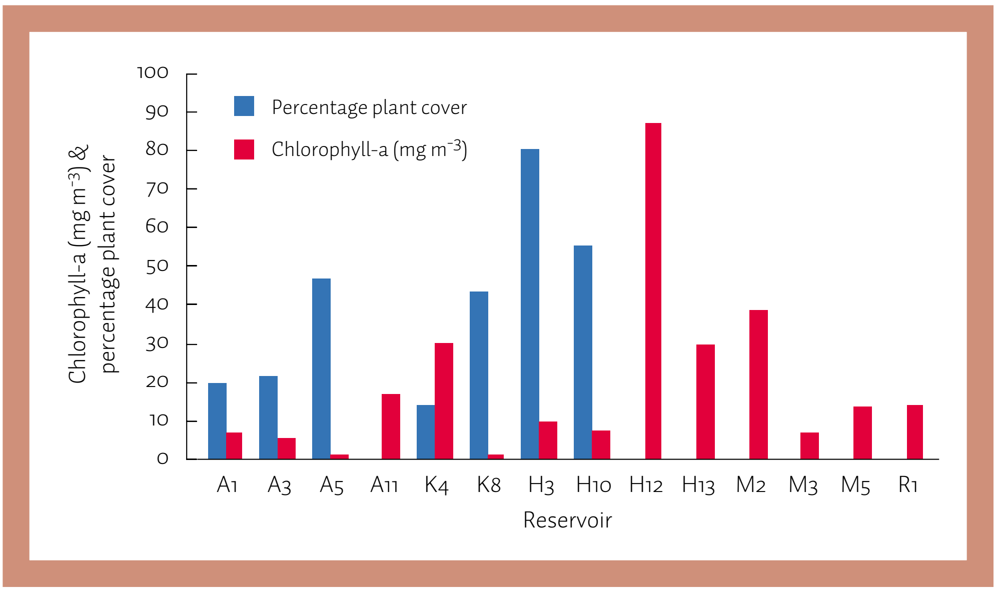

Figure 40. Chlorophyll-a and percentage plant cover of some seasonal reservoirs in five administrative districts of Sri Lanka (A–Anuradhapura, K–Kurunegala, H–Hambantoa, M–Monaragala and R–Ratnapura).

Sustainability

One of the main factors influencing success of culture-based fisheries in non-perennial reservoirs is the economic viability of the strategies at all levels of production. As can be seen from Figure 36, the entire strategy involves the following four steps:

1. Induced breeding of major carps in state-owned fish breeding centres;
2. Rearing of post-larvae to fry stage in cement ponds under controlled conditions in state-owned fish breeding centres;
3. Rearing of fry to fingerling size in earthen ponds owned by villagers and net cages installed in perennial reservoirs through community participation; and
4. Stocking of fish fingerlings in non-perennial reservoirs and harvesting after a growth period of 7–9 months for marketing.

There should be a reasonable profit at each stage of production for the three parties (i.e., state-owned breeding centre, fingerling rearers and fish farmers in non-perennial reservoirs) in order to sustain the entire strategy. Presently the cost of one fish fry is 25 cents and a fingerling is Rs. 1.50. On average, the farm-gate price of 1 kg of cultured fish is Rs. 40.

Table 7. Details of fish fingerling rearing trials in earthen ponds in two culture cycles (Adopted from: Pushpalatha 2001).

Pond area (m^2)	Species	No. of fry stocked	No.of fingerlings produced	Culture period (days)	% survival
172	*C. carpio* (cycle 1)	7000	4000	72	57
	L. rohita (cycle 2)	7000	4575	67	65
146	*C. carpio* (cycle 1)	6000	5000	65	83
	C. mrigala (cycle 2)	6000	4000	69	66
176	*L. dussumieri*	7000	3800	70	54
136	*C. carpio*	6000	2000	72	33
250	*C. carpio* (cycle 1)	10000	3800	71	38
	L. dussumieri (cycle 2)	10000	5600	63	56
350	*C. carpio*	10000	5800	68	58
540	*L. dussumieri*	10000	8000	76	80
350	*C. carpio* (cycle 1)	15000	10000	78	66
	L. rohita (cycle 2)	8000	4200	62	53

In Sri Lanka, this whole process is dependent on the demand for fish fingerlings for stocking in non-perennial reservoirs. However, the decision on whether to stock a non-perennial reservoir is determined by reservoir filling in November–January, which is beyond human control. Thus, an alternative means to stocking fish fingerlings that were reared in earthen ponds and net cages is needed. This is to assure a market for fish fingerlings when there is no demand for fish fingerlings during dry years. As fingerlings are not required for stocking in non-perennial reservoirs during all seasons, they can be stocked into small perennial reservoirs (Chandrasoma 1992). Amarasinghe (1998) has shown that in small (<800 ha) perennial reservoirs, where the fisheries based on cichlids are not productive, stocking of fingerlings of major carps might increase yields.

Table 8. Details of fish fingerling rearing trials in net cages in eight perennial reservoirs in two culture cycles (Adopted from: Pushpalatha 2001). Cage size: 4 m x 2.5 m x 2 m; Stocking density: 5000 fry per cage.

Reservoir (area)	Species	Number of fingerlings harvested	Culture period (days)	% survival
Bellankadawala (66 ha)	Red tilapia (cycle 1)	3000	77	60
	O. niloticus (cycle 2)	3050	61	61
Ellewewa (168 ha)	Red tilapia (cycle 1)	4600	70	92
	L. rohita (cycle 2)	4408	65	88
Giritale (360 ha)	*L. rohita* (cycle 1)	4000	61	80
	C. carpio (cycle 2)	4100	64	82
Mahakanadarawa (1157 ha)	*C. carpio* (cycle 1)	4000	62	80
	L. dussumieri (cycle 2)	3800	65	76
Nuwarawewa (1197 ha)	*C. carpio* (cycle 1)	4500	72	90
	L.dussumieri (cycle 2)	4200	65	84
Pimburettewa (830 ha)	Red tilapia (cycle 1)	2800	70	92
	C. carpio (cycle 2)	3000	67	88
Ranawa (60 ha)	*C. carpio* (cycle 1)	3000	80	60
	L. rohita (cycle 2)	3500	64	70
Willachchiya (972 ha)	*C. carpio* (cycle 1)	2750	58	55
	L. dussumieri (cycle 2)	3700	63	74

Reservoir area and culture-based fisheries yields

Results of recent culture-based fisheries trials in 11 seasonal reservoirs of Sri Lanka are presented in Table 9. In these reservoirs, five species were stocked: Nile tilapia- *Oreochromis niloticus*, hirikanaya- *Labeo dussumieri*, common carp- *Cyprinus carpio*, rohu- *Labeo rohita* and mrigal-*Cirrhinus mrigala*.

A more detailed analysis also indicates that the yield of a culture-based fishery is negative (curvilinearly) when related to reservoir area (Figure 41). These results indicate that small (<10 ha) seasonal reservoirs are more suitable for the development of culture-based fisheries than larger seasonal reservoirs.

Jarchau et al. (2005) have shown that the working days of fish farmers per hectare are negatively related (curvilinearly) to reservoir area (Figure 42). This indicates that development of CBF in smaller reservoirs (about 5 ha) is more feasible than in larger perennial reservoirs.

Table 9. Stocking densities (SD; Numbers/ha)) and yields in 11 seasonal reservoirs in Anuradhapura district, Sri Lanka during the 1998/1999 and 1999/2000 culture cycles. Here, area of a seasonal reservoir is considered as 50% of the extent at the full supply level (i.e. effective area). The SD and fish yield are estimated for the effective area of each reservoir (Amarasinghe and Pushpalatha 2004).

Reservoir	Area (ha)	SD	Yield (kg/ha)
Bulankulama	4.0	1630.2	350.74
Galpoththegama	18.2	510.5	40.51
Gulupeththawewa (1998/1999)	5.1	1363.4	84.57
Gulupeththawewa (1999/2000)	5.1	2035.3	160.65
Karambegama	9.5	1140.4	113.51
Karambewa	3.0	5763.0	785.79
Luneathulewa	9.1	2360.2	196.94
Maha Ralapanawa	8.9	2267.9	384.20
Pandikgama	3.0	6586.0	559.87
Rathmalgahawewa	2.6	2280.0	180.5
Thimbalawewa	6.5	3149.3	307.52
Viradagollewa	3.2	6329.0	953.11

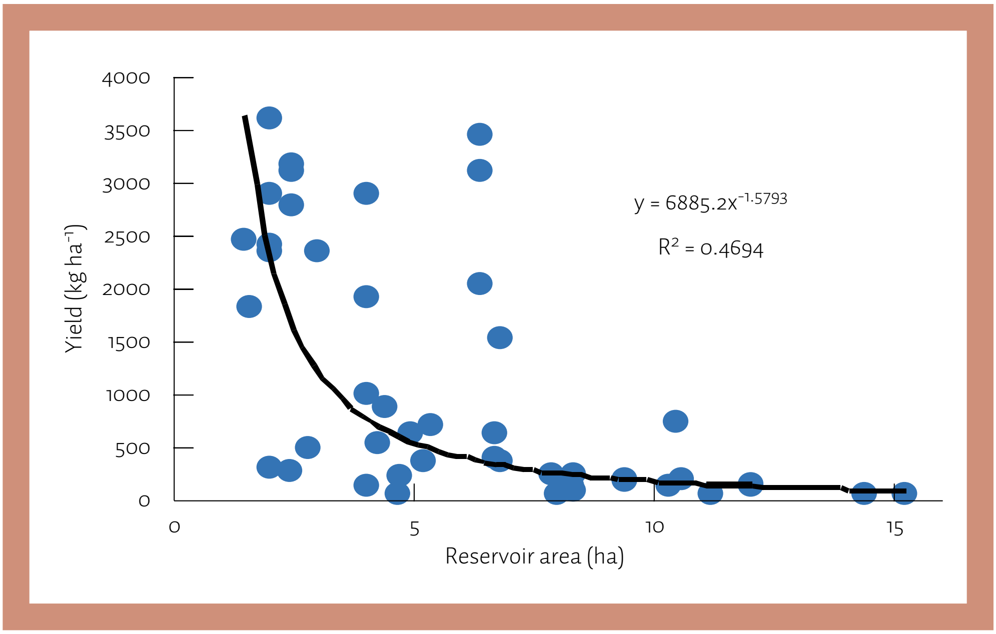

Figure 41. Curvilinear relationship between fish yield and reservoir area in some seasonal reservoirs in Hambantota, Monaragala, Ratnapura, Anuradhapura and Kurunegala districts, Sri Lanka.

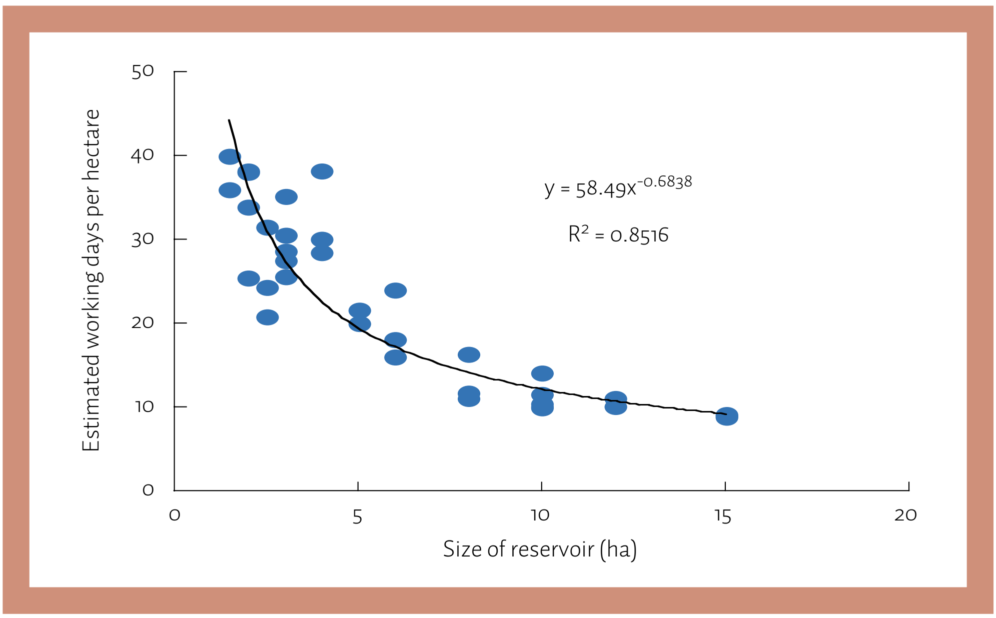

Figure 42. Relationship between size of reservoir and working days per hectare (Source: Jarchau et al. 2005).

Factors influencing culture-based fisheries yields

Culture-based fisheries yields in non-perennial reservoirs are correlated to chlorophyll-a content (Figure 43). It has also been shown that fish yield is higher in the reservoirs with high buffalo density (Athula et al. 2005), possibly due to the nutrient loading through buffalo dung.

Stocking efficiency (yield per stocked fish) is comparatively high for culture-based fisheries in non-perennial reservoirs (Figure 44) indicating high fisheries production potential. As indicated earlier (Figure 40), presence of aquatic macrophytes in non-perennial reservoirs causes low productivity.

As most non-perennial reservoirs are situated in cascade systems, some are connected to rivers and large perennial reservoirs so that carnivorous fish species, such as snakeheads, enter reservoirs. This is more pronounced in the reservoirs of Anuradhapura and Kurunegala districts. In reservoirs with snake-heads, higher instantaneous mortality rates of stocked species were evident compared to those without snakeheads (see Figure 11 in Section 1.3.2).

Development of a ranking system for non-perennial reservoirs

In view of the large number of seasonal reservoirs in Sri Lanka, there is a need to rank the suitability of them for developing culture-based fisheries. To develop a suitable ranking system or scale, aspects such as the physico-chemical, biological, catchment and hydrological characteristics of the water bodies, as well as socio-economic aspects need to be taken into consideration. Accordingly, De Silva et al. (2004) performed a preliminary analysis to develop a ranking system to determine the suitability of 14 non-perennial reservoirs in southern Sri Lanka. The ranking was achieved using a Geographical Information System (GIS) and an Analytic Hierarchy Process (AHP). The latter permits a set of heterogeneous factors to be equated to a common denominator (Saaty 1977). Thematic layers of water quality, catchment characteristics, market related aspects and socio-economic factors corresponding to each of the reservoir studies were evaluated using scores that were obtained using a weighted linear combination.

The final weightings for each of the 14 reservoirs indicated that none of the reservoirs could be considered as 'poor'; one reservoir was considered as 'excellent', six reservoirs were considered as 'fair' and the remaining seven reservoirs were considered 'good'. As these results indicate that is possible to develop a ranking system, further research is being carried out in five administrative districts of Sri Lanka.

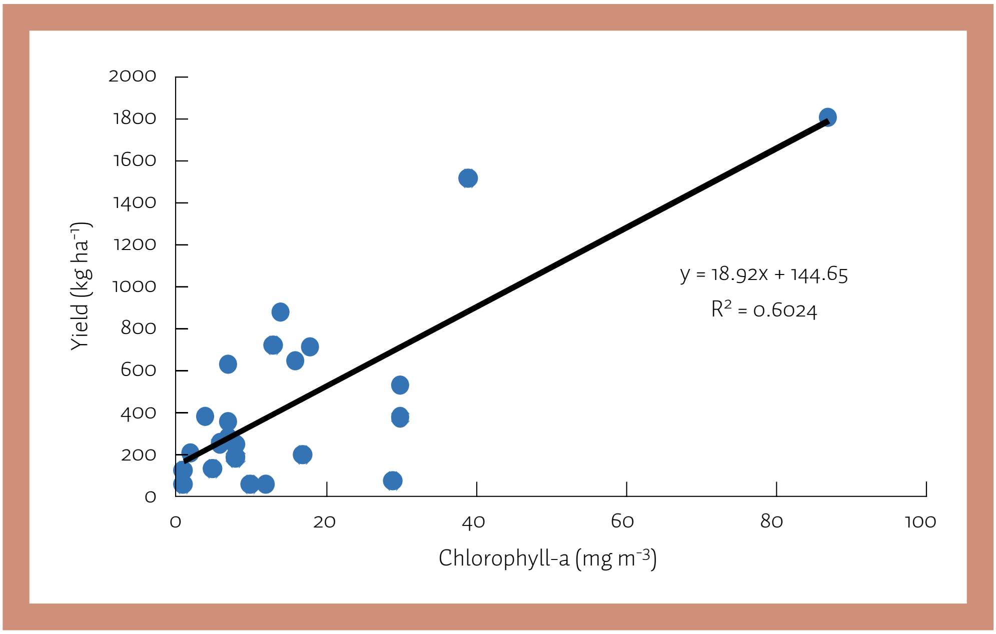

Figure 43. Relationship between yield and chlorophyll-a content of seasonal reservoirs.

Summary and Conclusions

In Sri Lanka, the extensive availability (>39,000 ha) of non-perennial reservoirs, which usually dry-up completely during July–September and fill during inter-monsoonal rains in December–January, will permit the development of culture-based fisheries. Due to high yields, culture-based fisheries in seasonal reservoirs provide a means of increasing the food supply in rural areas of Sri Lanka. This could benefit the poor sectors of the rural communities significantly.

There are environmental concerns with regard to intensification of aquaculture. Naylor et al. (2000) highlighted that the use of fishmeal in aquafeeds causes detrimental effects to capture fisheries. Also, there has been an increasing emphasis on the need for fisheries management in an ecological context due to direct impacts on ecosystems which are also impacted by other human practices (Garcia et al. 2003). However, the culture-based fisheries in seasonal reservoirs of Sri Lanka have little impact on the environment: they are dependent on existing water bodies and involve minimal external inputs especially as supplementary feeds are not used. Under the inland fisheries development plan in Sri Lanka, net cage culture to rear fish fry to fingerlings in perennial reservoirs is promoted. It is expected that this aquaculture strategy will produce part of the fingerling requirement for the culture-based fisheries in seasonal reservoirs. However, it is unlikely that the cage culture for fish fingerlings will expand beyond an uncontrolled level due to high initial cost involved. Hence, from the

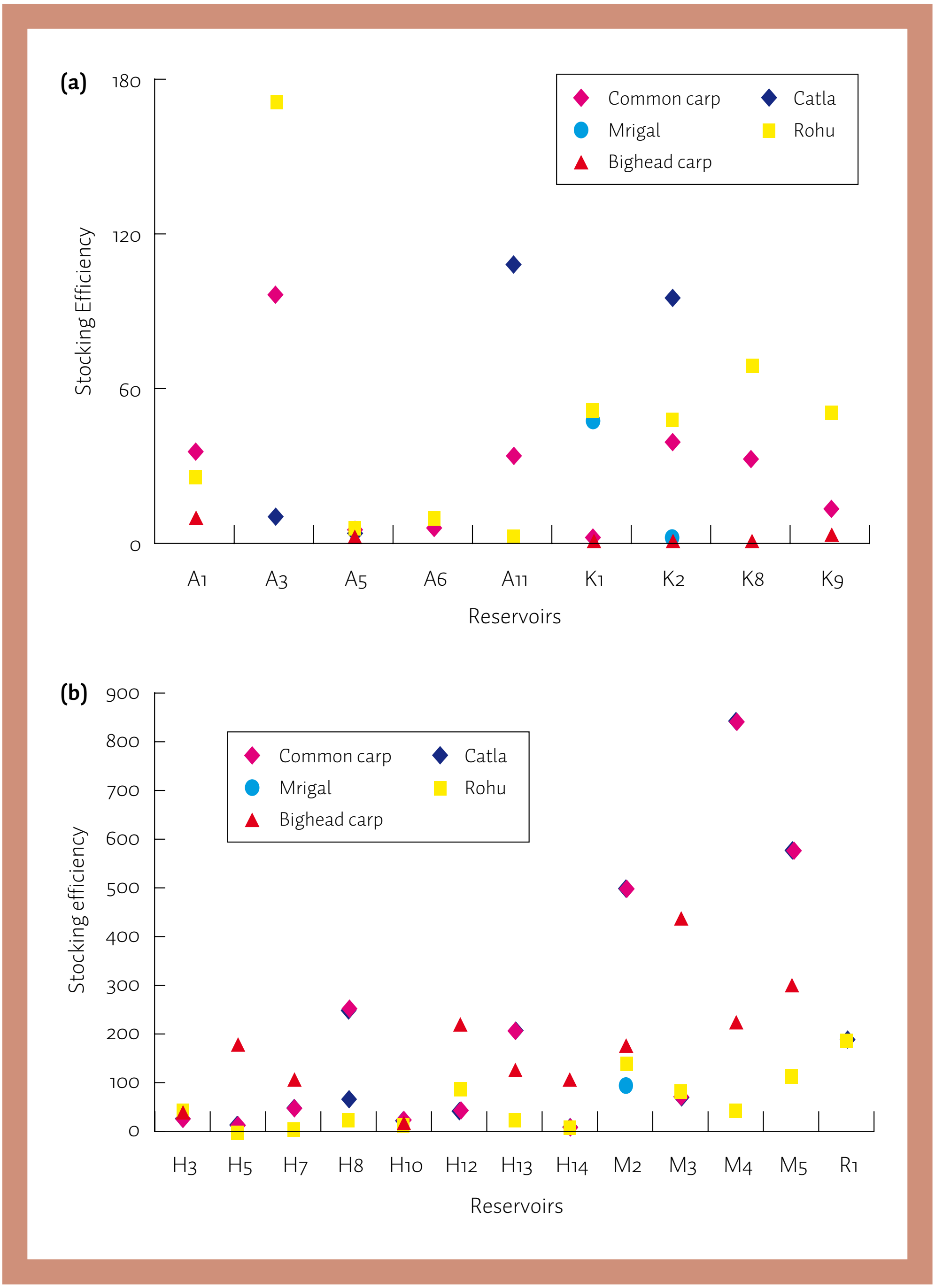

Figure 44. Stocking efficiency of fish species in non-perennial reservoirs (a) Anuradhapura and Kurunegala districts. (b) Hambantota, Monaragala and Ratnapura districts (A–Anuradhapura, K–Kurunegala, H–Hambantoa, M–Monaragala and R–Ratnapura) (Source: Wijenayake et al. 2005b).

point of view of biodiversity conservation and environmental protection, culture-based fisheries in seasonal reservoirs can be considered as a relatively eco-friendly development strategy.

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Culture-based fisheries development in Vietnam: a case study

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Reservoir resources in Vietnam

In Vietnam most reservoirs were built and developed about 30 years ago and for the purposes of hydro-electric power generation, flood control, transportation and irrigation. Small reservoirs, on the other hand, have been mainly built to store stream water for irrigation, especially to provide water in dry seasons. Culture-based fisheries are considered as the most appropriate management option for fish production in small reservoirs in Vietnam.

Based on data collected by the Research Institute for Aquaculture No. 1 in 1993, there were 768 medium and large reservoirs distributed across 38 provinces in the midland and highland regions, with a combined area of 115,549 ha in Vietnam (Thai 1995). Nguyen (1994) indicated there were about 2470 reservoirs with a total area of 183,579 ha in the country (Table 10). Among these reservoirs, there are 1430 greater than 5 ha in area (Nguyen Van Chinh et al., 1994). Ngo and Le (2001) also indicated that there are 4000 reservoirs with a total area of 340,000 ha. However, the current number of reservoirs is thought to be higher because recently many new reservoirs have been constructed throughout the country to meet the increasing demands of an increasing population.

From 1962 to 1970, fish culture was practiced in 16% of the reservoirs, occupying 48% of the total area (Nguyen 2000) and stocked species contributed 15–90% to the total reservoir production. Fluctuations in fish products depended on the situation of each reservoir and was closely related to the success of stocking activities. Stocking at that time appeared to be a very effective way of increasing fish production and generating economic benefits. The current yield from reservoirs is estimated at 5050 t/year which is approximately 43 kg/ha/year; the larger reservoirs averaging 10–15 kg/ha/year, and the smaller reservoirs averaging 100–500 kg/ha/year (Nguyen 2000). This level of production is one of the lowest in Asia. As a result, the fishery potential of these water bodies, in all probability, is not fully realised. Therefore, the Government of Vietnam, at present, considers reservoir fishery research and development as a priority.

Table 10. General status of reservoir fisheries in Vietnam in 1993 (Source: Nguyen Q A 2000).

Region	Reservoir area (ha)	Stocked		Production	
		No (%)	Area (%)	Total (t)	kg/ha
Northern provinces	63,667	3.4	10.3	370.4	56.4
Northern Central provinces	20,775	33.9	8.9	92	50.0
Southern Central provinces	11,196	7.1	43.9	192	39.1
Central Plateau	12,424	3.2	3.2	59.5	150.6
Eastern Mekong region	73,105	19.0	1.3	314	330.9
Total	181,167	7.6	8.1	1,027.9	70.1

CBF in Vietnam

In Vietnam, stock and recapture in reservoirs had been done since 1962 especially in reservoirs of around 1000 ha. The government built hatcheries for fingerling production for restocking programs in almost all large reservoirs. Even for some small sized reservoirs of 300–400 ha, hatchery stations were also built for enhancement purposes as well as for supplying seed to neighbouring fish farmers.

During the period 1970–1985, with successes in artificial breeding technology of cultivated fish species, the central and provincial governments provided strong support for the production of hatchery seed for restocking, which was carried out by fishery cooperatives (in all large and medium size reservoirs). Small irrigation reservoirs were managed by local irrigation departments.

In the last decade, in recognition of the importance and the potential of reservoir fisheries in meeting the increasing demand for animal protein, as well as providing additional employment in rural areas, the Government of Vietnam has encouraged farmers to use reservoirs for fisheries development. Moreover, the government clearly stated in the 10-year development plan that it was an objective to obtain a production level of about 50,000 t from reservoir fisheries development by the year 2010. Thus, most small irrigation reservoirs in Vietnam now are leased to farmers, farmer groups or any local organisation to conduct culture-based fisheries activities. Hence, culture-based fisheries have developed rapidly in recent years and fish products from these practices have contributed significantly to the total inland fish production in Vietnam.

Water quality in reservoirs

Research recently conducted in Vietnam indicates that fish yield was closely related to chlorophyll-a concentration and conductivity (Figure 45). Thus, water quality is considered to be one of most important factors that affect fish production in culture-based fisheries in Vietnam, as elsewhere.

Results of a study funded by ACIAR has shown that water quality of 20 small reservoirs in two typical provinces (Yenbai and Thainguyen) in northern Vietnam was poor in nutrients,

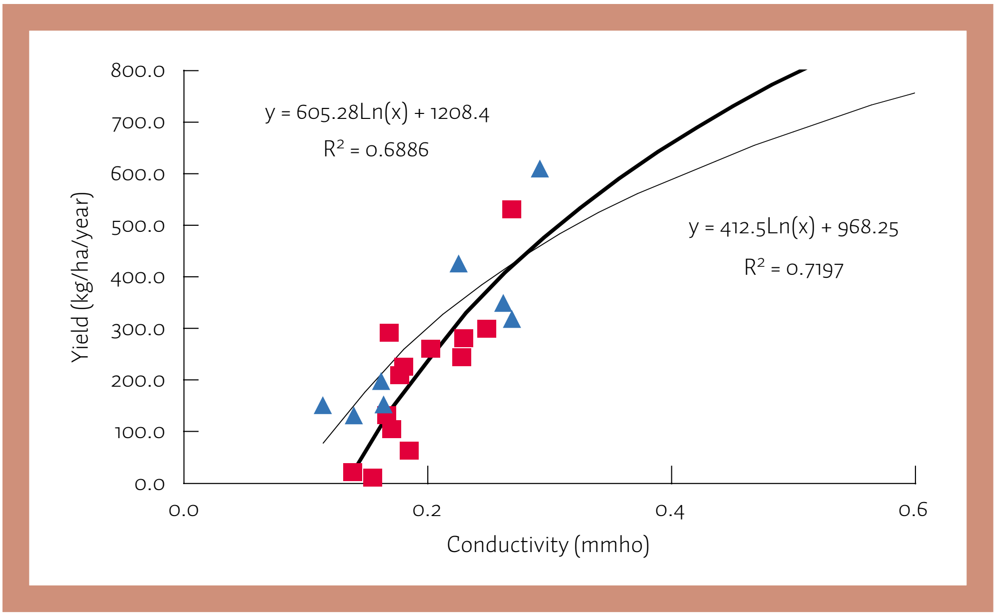

Figure 45. Relationship between yield (kg/ha) and conductivity (μmho) in 20 small reservoirs in northern Vietnam.

expressed by low nitrate (0.05–0.09 mg/L) and phosphorous (0.05–0.07 mg/L) concentrations, respectively (Nguyen et al. 2000). It also indicated that the reservoirs studied were relatively poor in primary production, indicated by a low concentration of chlorophyll-a and conductivity (Table 11).

In northern Vietnam, stocking is normally carried out from April to June when the water level is high. At this time, seed stock is readily available as this coincides with the breeding season of most species in Vietnam. The fish species stocked depends mainly on availability in the regions and proximity to the supplies. Fish species used for stocking generally include grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalamichthys molitrix*), big head carp (*Cyprinus carpio*), mrigal (*Cirrhinus mrigalla*) and silver barb (*Barbodes gonionotus*); silver carp and mrigal are the two major species (40–50%) stocked. This is not only because the seed of these two species is relatively cheaper and easier to harvest, but also their feeding habits are considered to be more suitable to the reservoir environment in Vietnam. The growth rate of five species in 12 typical reservoirs in northern Vietnam is shown in Figure 46.

Generally, the stocking density ranged from 27 to 144.8 kg/ha, corresponding to 200 to 1100 individuals per hectare for small farmer-managed reservoirs (5–30 ha) (Table 12), which is in the higher range for large- and medium-size reservoirs (10–20 individuals/ha). In recent years, advanced technology has been applied to small reservoirs aiming at semi-intensive culture of mono-sex tilapia. This experiment provided high fish production (3000 kg/ha). However, the seed supply for stocking into reservoirs was inadequate and the quality of seed was also not good. For example, breeding occurred, indicating that not all of the stocked

Table 11. The overall mean (±SE) of selected limnological parameters in 20 reservoirs located in northern Vietnam. nd - not determined (Source: Nguyen and De Silva 2003).

Parameter	2002						2003					
	ThaiNguyen			YenBai			ThaiNguyen			YenBai		
	S	1 m	2 m	S	1 m	2 m	S	1 m	2 m	S	1 m	2m
Temperature (°C)	28.2 (±0.8)	27.4 (±0.7)	26.3 (±1.7)	28.5 (±0.6)	27.5 (±0.6)	25.1 (±0.9)	28.5 (±0.7)	26.9 (±0.7)	26.3 (±0.3)	28.6 (±0.3)	26.8 (±0.4)	26.3 (±0.4)
DO (mg/L)	6.3 (±0.2)	5.1 (±0.3)	3.4 (±0.3)	5.8 (±0.2)	4.3 (±0.2)	2.9 (±0.3)	6.1 (±0.2)	4.8 (±0.2)	3.1 (±0.2)	5.9 (±0.2)	3.9 (±0.3)	2.5 (±0.1)
Conductivity (µS)	72.5 (±9.4)	71.8 (±9.4)	65.3 (±6.0)	102.8 (±4.9)	103.1 (±5.3)	107.5 (±7.9)	73.9 (±7.0)	74.5 (±7.0)	75.1 (±7.0)	97.1 (±5.6)	98.3 (±5.9)	98.8 (±5.9)
pH	7.4 (±0.1)	nd	nd	7.5 (±0.1)	nd	nd	7.5 (±0.1)	nd	nd	7.7 (±0.1)	nd	nd
Alkalinity (mg/L)	32.8 (±0.1)	nd	nd	37.1 (±2.0)	nd	nd	24.1 (±2.1)	nd	nd	37.8 (±2.8)	nd	nd
Nitrate (mg/L)	0.06 (±0.02)	nd	nd	0.05 (±0.01)	nd	nd	0.1 (±0.05)	nd	nd	0.09 (±0.02)	nd	nd
Phosphate (mg/L)	0.07 (±0.03)	nd	nd	0.05 (±0.01)	nd	nd	0.06 (±0.02)	nd	nd	0.07 (±0.02)	nd	nd

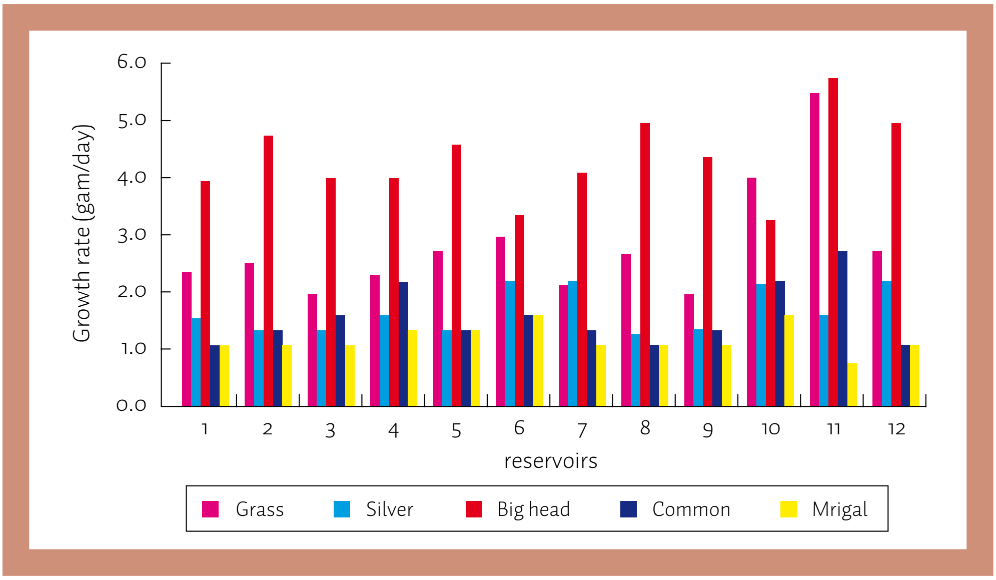

Figure 46. Growth rate of stocked species in reservoirs in northern Vietnam (Adopted from: Nguyen et al. 2001).

fish were the same sex. This resulted in overcrowding and the size of fish at harvesting was relatively smaller resulting in reduced prices.

Size of fish stocked also varied depending on the species as well as availability. The size of stocked species now used in Vietnam reservoirs normally is:

- Silver carp, big head carp 13–15 cm;
- Mud carp, Indian major carp, common carp 10–12 cm;
- Grass carp 18–25 cm; and
- Tilapia 6–8 cm.

In northern Vietnam, paddy culture normally requires more water during the period from March to May. Thus during this time, the water level in most small reservoirs is at the lowest point, so fish harvesting is normally done during this period. Basically, fish are harvested once per year after stocking. Data collected by Nguyen et al. (2004) have shown that stocked fish remain an important source of the fish harvest in small reservoirs, contributing more than 80% to the total weight at harvest. In large reservoirs, the proportion of stocked species contributed up to 40% (Table 13).

The size of fish harvested normally varies between species and this may be partly due to size differences at the time of stocking. The mean weight of each species at harvest in culture-based fisheries in Vietnam was: grass carp 0.8–1.5 kg; silver carp 0.5–0.8 kg; big head carp 0.8–2.0 kg; common carp 0.3–0.7 kg; mrigal 0.3–0.6 kg; and tilapia 0.3–0.4 kg. The variation in yields between reservoirs in northern Vietnam was found to be significant and ranged from 115 to 429 kg/ha. The average yields were 238±89.3 in 2001 and 271±45.7 kg/ha in 2002 (Nguyen et al. 2001; 2005). High variation in yields between reservoirs may be related to the size of each reservoir and generally, yields were lower in the larger reservoirs (Figure 47).

Table 12. Stocking density (kg/ha) in 2001 and 2002 in 20 small reservoirs located in northern Vietnam (Source: Nguyen et al. 2005).

Reservoirs	Areas (ha)	S. density (kg/ha)	
		2001	2002
Phu Xuyen	5	48.3	52.2
Tho Hong	5	36.3	45.9
Da Gian	4.5	50.3	95.9
Doan Uy	7	28.7	27.8
Phuong Hoang	4.5	30.9	36.5
Ban Co	8	45.9	61.8
Dong Mang	8	42.2	55.3
Xuan Do	5	31.0	29.2
Khe Say	8	47.8	67.5
Khe Muong	6.5	109.8	144.8
Thinh Hung B2	7	178.9	219.6
Lo Xa	20	117.0	140.4
Dam Chem	18	62.0	82.0
Khuan Gio	20	161.5	96.6
Hong Bang	8	83.8	90.8
Ao 5	22	111.4	120.0
Van Hoi	20	63.0	68.8
Van Hung 4A	8	99.1	120.3
Tan trung	4.5	87.1	81.3
Dong Ly II	30	67.3	74.6

Stocking efficiency

Stocking efficiency is defined as the ratio of yields of stocked fish (kg/ha) to the weight of fish stocked (kg/ha) (Li 1987). Previous research has shown that there was a significant difference in the stocking efficiency of large and small reservoirs. The range for stocking efficiency in large reservoirs was 1.5–5 kg/ha and 6.95–22 kg/ha small reservoirs. According to Li (1987) large reservoirs in Vietnam had a poor (less than 5) stocking efficiency, whereas small ones ranged between good to excellent.

Table 13. The yield of stocked fish, wild fish and the percentage of wild fish weight froms harvests of 20 reservoirs in 2002 and 2003 in northern Vietnam. Yield S. fish: (Source: Nguyen et al. 2005)

Reservoir	Stocked (2002) (kg/ha)	Wild (2002) (kg/ha)	% wild	Stocked (2003) (kg/ha)	Wild (2003) (kg/ha)	% wild
Phu Xuyen	183.4	38.9	17.5	196.3	38.9	16.5
Tho Hong	116.5	12.5	9.7	130.0	60.0	31.6
Da Gian	265.3	27.5	9.4	419.6	187.5	30.9
Doan Uy	115.5	10.9	8.6	156.6	24.3	30.0
Phuong Hoang	134.4	32.5	19.5	137.5	40.0	22.5
Ban Co	127.5	15.0	10.5	157.1	25.0	13.7
Dong Mang	238.0	15.6	6.1	276.9	33.3	10.7
Xuan Do	138.8	28.3	16.9	149.2	53.3	26.3
Khe Say	227.5	20.0	8.1	263.3	37.5	12.5
Khe Muong	429.5	75.0	14.9	393.3	75.0	16.0
Thinh Hung B2	349.3	55.6	13.7	374.0	100.0	21.1
Lo Xa	266.9	92.9	25.8	271.9	50.0	15.5
Dam Chem	277.0	40.0	12.6	385.3	170.0	30.6
Khuan Gio	395.6	43.8	10.0	469.1	92.5	16.5
Hong Bang	279.4	112.5	28.7	296.6	125.0	29.6
Ao 5	341.6	10.0	2.8	429.4	64.0	13.0
Van Hoi	202.8	20.0	9.0	195.4	106.3	35.2
Van Hung 4A	219.4	46.2	17.4	289.2	132.3	31.4
Tan trung	267.7	34.3	11.4	241.4	92.9	27.8
Dong Ly II	192.4	71.7	27.1	292.2	95.8	24.7
Average	238.4±89.3	40.1 ±27.8		271.2 ±45.7	80.2 ±7.6	

Economic efficiency

For culture-based fisheries in farmer-managed reservoirs, the current net annual net income ranges from 0.485–0.725 million VND. In most instances this is additional income to their normal farming activities, so provides a significant supplementary income. This relatively low net income from this fishery is a result of the low yields obtained, and the very wide range in yields among reservoirs. The latter cannot be fully explained on the basis of 'reservoir difference' as a major contributing factor is likely to be the poor husbandry practices that are adopted. The development of a best-practice model for the reservoirs is expected to increase significantly the net gains from culture-based fisheries. Accordingly this will increase the economic gains of the farmer.

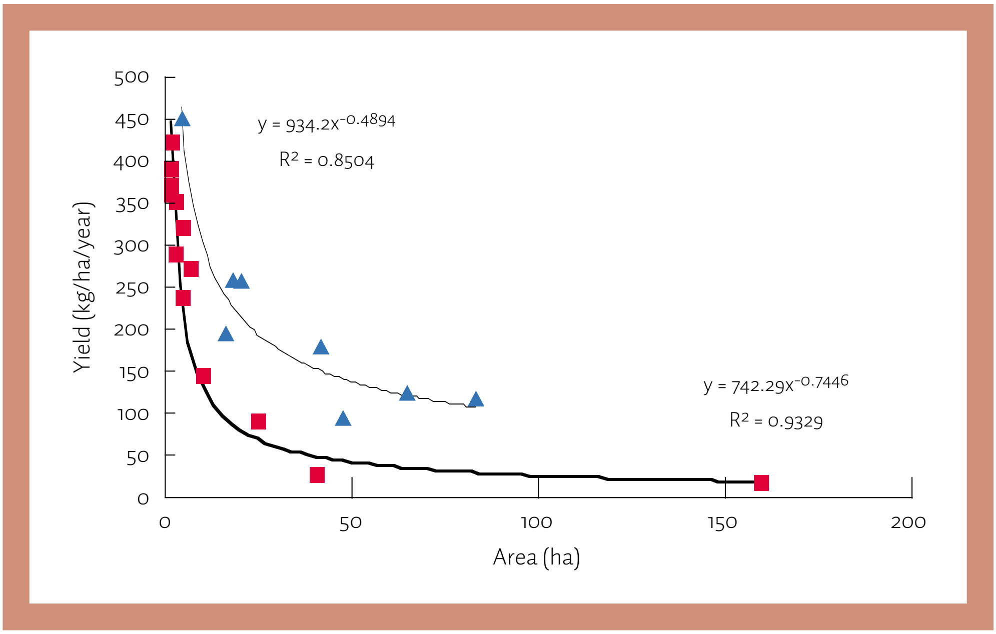

Figure 47. Relationship between area (ha) and yield (kg/ha) in 20 typical reservoirs from two provinces in northern Vietnam (Source: Nguyen et al. 2001).

Culture-based fisheries development program in Vietnam

Environmental enhancement

Previous work indicates that the natural productivity of most of farmer-managed reservoirs was relatively low. Thus a strategy to increase natural productivity through the use of organic manures should be examined. However, careful consideration of the possible impact on the environment is needed before this option is used. Environmental considerations and the possible conflicts of interest among various water users, as well as competing use for organic manures, are the main factors that prevent the wide use of this option.

Improvements to stocking strategy

Increasing stocking density and the size at stocking may well be a useful way to increase fish production in Vietnam's reservoirs. However, currently the seed stock used in culture-based fisheries is almost entirely dependent on the financial capabilities of the farmers; and to a lesser extent on fingerling availability. However, as culture-based fisheries develop further, it is expected that there will be more emphasis laid by provincial governments on seed stock supplies. This could lead to increased availability of good quality seed in the regions, at an affordable price. There is a possibility that credit lines could also be established to enable farmers to purchase seed stock.

Based on the fish species available as food resources available, production potential, and growth and mortality rates, five fish species are considered to be suitable for small farmer-managed reservoirs in northern Vietnam. Accordingly, the most desired species combination for culture-based fisheries in northern Vietnam has been determined and will be extended to the farmer lessees, and these are common carp, grass carp, bighead carp, silver carp and mrigal.

Staggered harvesting

Staggered harvesting plays an important role in the income of farmers. Normally, in small farmer-managed reservoirs, fish are harvested within a narrow time frame. This has the potential to lead to an oversupply of fish, resulting in lower returns to the producer and affecting their income. This is a common feature seen in other countries with culture-based fisheries.

Conclusions

The overall goal of the current studies undertaken in Vietnam is to provide information and relevant advice to the Ministry of Fisheries, Vietnam, to support national development efforts to significantly increase fish yields from reservoir resources. The better-practice model for culture-based fisheries will also include statistical models that could be applied throughout the country to support the efforts of the Government of Vietnam in maximising fish yields from small farmer-managed reservoirs.

In Vietnam, most small irrigation reservoirs are seen as appropriate for developing culture-based fisheries. Due to their location, mostly in remote areas, culture-based fisheries provide a means for producing a cheap source of animal protein to meet the increasing demand for food in rural areas of Vietnam. As such, it could significantly benefit the poor sectors of the rural communities.

In some cases, farmer-managed reservoirs produced high yields. However, the benefit was still relatively low: primarily due to an oversupply of low-value fish, within a narrow time frame, resulting in a low return to the producer. It may be possible to minimise this problem through the introduction of high-value species, as well as through better regional coordination of harvesting and development of suitable market chains.

Currently, the farmer practices are ad hoc, particularly with regard to the benefits from culture-based fishery practices. It is expected that as suitable expertise is gained, culture-based fisheries in northern Vietnam will continue to develop and result in greater economic benefits to the practitioners.

Therefore, the Government of Vietnam considers reservoir fishery research and development to be a priority. The overall goal of the government is to provide information and train farmers. Farmers need to know that there are many approaches to developing a culture-based fishery. Further, suitably adopted practices could contribute substantially to the availability of fish supplies, at an affordable price to the rural poor, assist in poverty alleviation, and provide income generation opportunities for communities living in the vicinity of reservoirs.

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The marketing context – understanding demand for fish

Studies that are to be undertaken and considered prior to popularising culture-based fisheries practices

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Poor understanding of the demand for aquatic products has frequently undermined attempts to promote culture-based fish production. Therefore a marketing 'situation analysis' should be one of the first tasks undertaken prior to promoting and/or extending such an activity. Fingerling supply characteristics, essential for culture-based fisheries, must also be evaluated. Some of the main aims of such a study are to:

- Provide a basis for species selection, production and harvesting strategy;
- Predict future demand based on historic trends in demand and supply for target species and their substitutes (products with similar marketing, preparation and consumption qualities);
- Find out if there is a potential for cost-effective value addition through appropriate post-harvest processing steps;
- Understand who benefits (and loses) from existing market systems and how this might change as a result of the new activity;
- Assess how sustainable the activity is, i.e. in terms of profitability where the intention is to sell surplus production; and
- Assess where institutional and other support to marketing channels/ infrastructure (e.g. cold chain facilities) may be required to improve access to target groups.

A situation analysis is a commonsense approach to gathering information required to formulate marketing goals and strategy. It commences with the 'big picture' of macro-environmental influences, moving down through descriptions of the total market, competition, intermediaries/ consumers and, finally, product trends and distribution channels.

Key findings of a 12-month marketing situation analysis, conducted in the dry-zone of Sri Lanka, are presented in the following sections. The purpose was to assess the potential of stocking enhancements for increasing aquatic production from small, non-perennial reservoirs (tanks), with emphasis on identifying benefits for the poor. These reservoirs are the main focus of settlement in rain-fed areas of the country's low-land dry-zone.

After reviewing secondary information (i.e. national and regional production and commodity price statistics) interviews were conducted with:

- Fishers around perennial and seasonal reservoirs over 12 months;
- Wholesalers and retailers at different levels of network in and around major irrigation systems in the north-west province;
- Retailers in urban areas (Kandy and Colombo) to establish an overview of fresh inland fish and substitutes (processed fish, marine fish, livestock, vegetables); and
- Consumers, using ranking and scoring exercises, to establish consumption patterns and preferences in dry-zone villages.

As you read through the following case study, try to compare the findings with what you know about marketing conditions in your own country. Think about the underlying reasons for those differences and, where methods are presented, think about how you might adapt them to your own circumstances.

Evaluating secondary data

Secondary data are pre-existing data (usually quantitative) collected by others and re-used to pursue a research interest distinct from the original work. Primary data are collected directly by the researcher. Commencing a market survey with a review of secondary data will: (1) reduce the chance of duplicating existing work; and (2) offer the ability to view current markets in a context of longer-term change if time-series data sets are available. Further, the use of progressively disaggregated secondary data can be used to target suitable areas and groups for development activities.

The following example highlights the need for a critical assessment of secondary production data which is a basis for national policy on inland fisheries management (including stocking). Official production statistics (Figure 48) indicate an exponential rise in Sri Lanka's inland fishery yields corresponding with the development of a fishery for exotic tilapias that were first introduced in the 1950s. The same figures then suggest a dramatic crash and rebound which is commonly attributed to withdrawal of state support to the inland fisheries sector between 1989 and 1994. In fact, both the trend and 'cause' are suspect for the following reasons: firstly, no official fisheries inspection capacity existed during the withdrawal; and secondly, a temporary surge in production is more likely to result from the kind of de-regulation observed here. Moreover, since there has been negligible resumption of stocking, and the effectiveness of previous stocking in large perennial reservoirs remains unproven, the rebound is most likely due to increased fishing effort on self-recruiting stocks and/or simply re-establishment of monitoring capacity.

Where there are limited resources for collection and validation of production statistics, as is frequently the case in developing countries, commodity price records may be a useful alternative. These data are easier to collect and are often readily available from governmental/research institutions. It is also a useful means for assessing competition from substitutes; both perfect (e.g. other types and forms of fish) and imperfect (e.g. other types of meat and in Sri Lanka, even certain vegetables). This is a critical point, as the seasonal supply and pricing of these goods, especially perfect substitutes, will ultimately determine the ceiling and floor prices of the new produce.

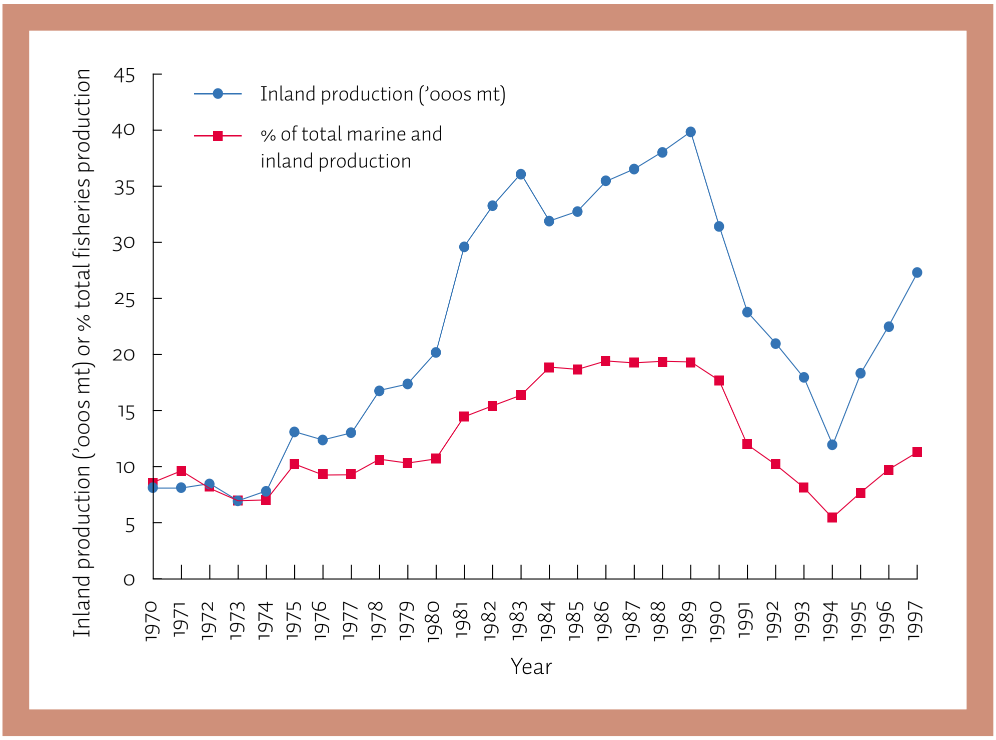


Figure 48. Inland fish production in Sri Lanka 1970–1997 (Source: NARA Fisheries Year Book 1998)

An additional problem associated with official production statistics is that they invariably focus on commercial landings and under-report subsistence production. In developing countries such 'invisible' production, destined mainly for local consumption in rural areas, can be considerable. Moreover, smaller (often seasonal) water bodies, which provide much of this production, also have greatest potential for culture-based fisheries under common property regimes. Therefore, it is important to understand the existing contribution of these fisheries to livelihoods if attempts to modify them are not to be counter-productive. By integrating supply and demand factors, an analysis of commodity price levels is probably the simplest means to evaluate the contribution of subsistence production toward total demand for fresh water fish.

Figure 49 shows a useful way to summarise large volumes of price data with standard deviation bars indicating the degree of weekly variation around monthly means. In terms of marine fish consumed by the poor, sardines and other low cost species, such as herring and anchovies, are the main substitutes for tilapias; and are similarly priced. Tuna, one of the highest cost marine species, is also shown for comparison. Price fluctuations are greatest for fresh marine varieties due to adverse weather conditions, seasonal species migrations, lack of cold storage and other factors related to processing capacity. Most marine fish is transported on ice from a limited number of plants around major landing sites and markets; this lack of capacity is far less critical to the inland sector due to the close proximity of production and consumer bases.

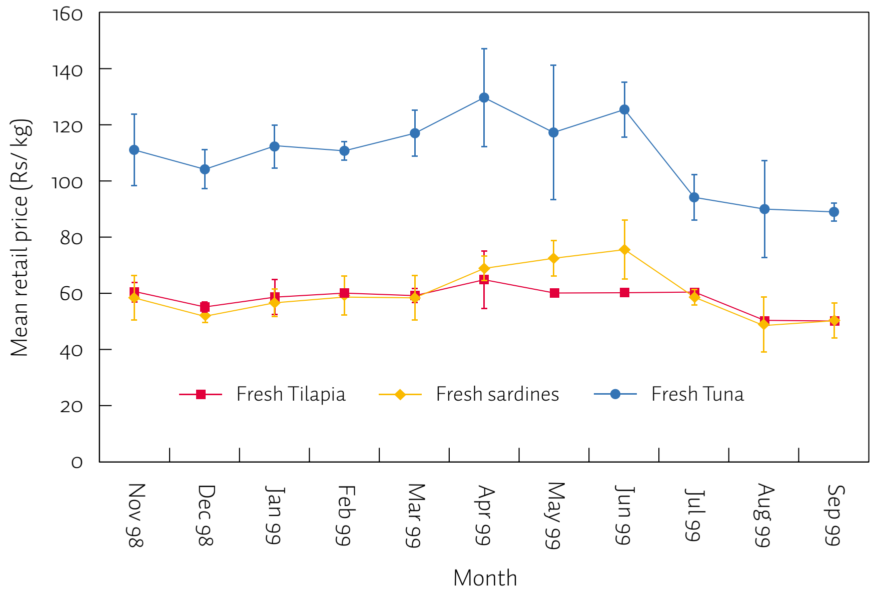


Figure 49. Mean monthly retail prices and standard deviations in weekly prices, for fresh marine and inland fish varieties, Colombo 1998–99. (Source: ARTI fish price index 1988–99. In: Murray 2000.) (For reference, agricultural labourers typically earned between Rs 150–200/day during the same period.)

By contrast, despite fears of over-exploitation, supply and demand for tilapia, appear remarkably well-matched both seasonally and historically. Figure 48 shows a fluctuation in retail price of only 17% over the year. Longer-term stability was confirmed by correcting prices for inflation, a compound rate of 103% between 1992 and 1998. Tilapia prices maintained close parity with inflation (even during the withdrawal of state support), while the erratic rise and fall of sardine prices underscores the relative instability of the marine market.

Such differences are -reinforced by a demand segmentation that is a consequence of geographic accessibility and income disparities. Coastal and better-off urban communities (including those on main roads) prefer marine fish. Whereas, in rural inland areas of Sri Lanka's dry-zone, demand is predominantly for cheaper, locally available freshwater fish, mainly tilapia, supplemented with dried marine varieties.

Two important constraints to culture-based fisheries in Sri Lanka emerge from this analysis: (1) there is a lack of established demand for inland fish in more lucrative urban markets; and (2) cultured-based species must compete with relatively low cost tilapias from capture fisheries in rural areas.

Seed and fingerling supply

A sustainable supply of suitable fingerling varieties, available when required at a particular size is a requisite for culture-based fisheries (as noted earlier in this manual). A market analysis should evaluate existing markets with particular emphasis on private sector incentives to produce and supply such seed. The fate of state fingerling production facilities during the withdrawal of state support in Sri Lanka (Figure 48) also provides a useful lesson in this respect. Most of these hatcheries were long-leased to the private sector operators, who, switched almost entirely from food fish to more lucrative ornamental fish production. This demonstrates that under current market conditions, culture-based fisheries in Sri Lanka cannot be expected to rely on the private sector for their fingerling supply. This is a major constraint to development. Alternatives must be considered, such as resuming support from the public sector and/or non-government organisations and developing community-based production systems, though these options too must be evaluated critically in terms of their sustainability.

Value addition

An analysis of marketing margins (considering production, wholesale and retail costs) indicates that drying fish represents salvage rather than a value addition strategy. Fresh fish commands the highest margins, which are shared equitably at different levels of the market chain, because of its competitive local structure (next section). Deficits for fresh fish are made up with cheap, imported and dried marine varieties.

Marketing networks for inland fish

Next, it is appropriate to consider briefly the commercial networks into which surplus production from village reservoirs in Sri Lanka might be marketed (Figure 52). This useful first step in primary data collection is based on interviews with network participants and consumers, and direct observations at different market levels. The market is based on two distinct production sources: artisanal fisheries in perennial reservoirs, supplying numerous adjacent villages settled around smaller village reservoirs (Figure 50); and produce from the more numerous smaller reservoirs. Supply of the latter produce is much less predictable, being constrained by the multi-purpose use of the reservoir and availability of water. In small reservoirs, most fish is produced seasonally and consumed locally. The following points are some of the main production characteristics of these two sources:

Production in seasonal village reservoirs

- The productivity of small seasonal reservoirs (<10 ha) depends on linkages with the watershed as a whole so fish availability varies within and between seasons (this is prior to the commencement of culture-based fishery practices).

- Natural repopulation of seasonal reservoirs is through the movement of fish, including tilapia and snakehead, from perennial refuges lower down the watershed.
- Harvest occurs mainly in the dry season for subsistence purposes with any trading limited to a few casual participants. Traders are deterred by erratic availability and negative consumer perceptions associated with muddy/soapy off-flavours attributed to smaller darker tilapia from seasonal reservoirs.
- Long-standing cultural taboos, such as the access to the water bodies, associated with these subsistence fisheries are also much more persistent than in the recently established commercial sector. This limits participation to younger and mainly poorer males. Women receive only indirect benefit and are often critical of male participation.

Production in perennial reservoirs

- Naturally recruited tilapias constitute between 75–90% of the harvest of fish gill-netted using canoes throughout the year (Figure 50). In recent years, entrant numbers have been increasing: mostly fisher–farmers living around the large reservoirs.
- This unregulated (relatively) fishery is resulting in a declining average size of individual fish and a loss of indigenous species from the catch.
- Production peaks during the two dry seasons when water levels are low (March–April and July–September) and during spill events (November–January).
- Fish are marketed mainly through a short chain of wholesalers and mobile retailers that service rural areas. Vendors using bicycles predominate over shorter distances (Figures 50 and 51) and sell smaller quantities (typically 10–20 kg/day) than those using motorbikes covering a greater range and selling larger quantities (typically 30–50 kg/day).
- In the dry season, when fish are most abundant, larger wholesalers truck tilapias to urban centres and the coast.

The conventional marketing networks for marine fish and higher value inland fish overlap marginally with that of tilapia sold by poorer traders in rural areas. Fish are generally sold whole and fresher fish are the most marketable. Common carp, which are the only exotic carp established in the fishery, are sold at prices similar to large tilapias, but often after processing into portions, increasing risk of spoilage (Figure 51). Higher value, niche freshwater species include the snakehead (*Channa striata*) and several eel species.

Consumer preferences

Unfortunately, consumers themselves tend to be given least consideration in many marketing studies of this kind. In the following exercise, 220 consumers in four villages were asked to rank which fresh fish or meat varieties they most preferred to eat (Figure 52). Mean ranks for the whole sample are shown in Table 14. Statistical analysis indicated that large tilapia, snakehead and wild game were significantly more popular than all other items. These locally sourced foods were all associated with freshness and quality—so much so

Figure 50. Bicycle vendors purchase tilapia from a landing site on a major reservoir at first light –note: wire mesh keep cage (right) and single outsize carp (centre) (Source: Murray 2004).

Figure 51. Large carps must be portioned for sale, increasing spoilage risk (Source: Murray 2004).

that many consumers associated use of ice for fish preservation as an indicator of inferior quality. A more detailed breakdown of results by different social criteria indicated that the poor prefer smaller, low cost tilapias, while wealthier individuals and those over 40 years old prefer costlier marine varieties.

Given that exotic carps are the main focus for culture-based fisheries, the intermediate ranking of common carp is of particular interest. Most respondents preferred common carp to marine fish, but felt that it was inferior to inland varieties of a comparable size e.g. larger tilapias and snakehead. Women and people over 40 years preferred them due to their relatively fleshy nature and ease of preparation. In other words, the current popularity of common carp appears to be part of an unfulfilled niche for larger sized fresh fish in general.

Table 14. Mean preference ranks for different types of fish and meat in four Sri Lankan dry-zone villages (n = 220) (Source: Murray, in preparation).

Fresh fish/meat varieties	Mean Rank
Large tilapia (>150 g)*	1
Snakehead*	2.5
Wild game*	2.5
Chicken	4.5
Common carp	4.5
Large marine fish (>150 g)	6.5
Small tilapia (<150 g)	6.5
Eggs and dairy products	8.5
Common labeo (*Labeo dussumieri*)	8.5
Small marine fish (<150 g)	10
Small indigenous species (SIS)	11
Beef and mutton	12

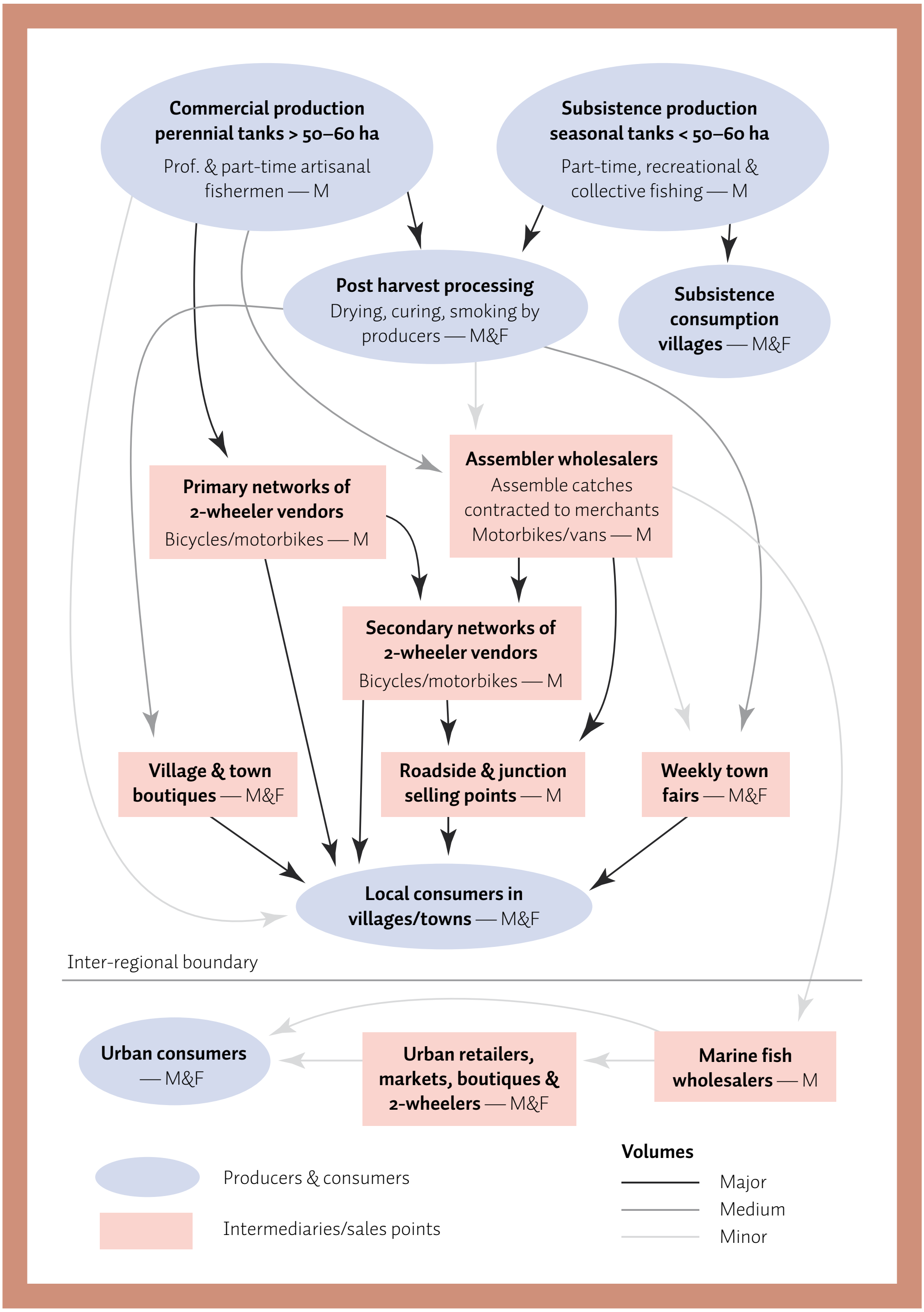


Figure 52. Principal marketing chains for inland fish in North-west Province, Sri Lanka: M = Male, F = Female, indicating likely participation (Source: Murray et al. 2000).

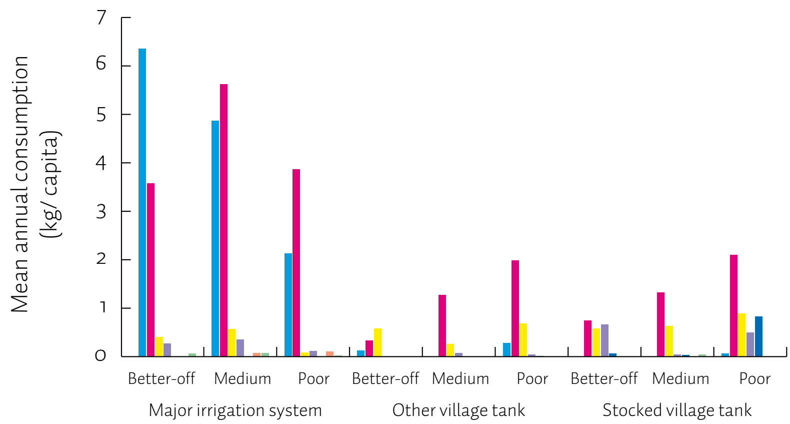
Figure 53. Ranking inland fish varieties using picture cards.

The vulnerability context

Prior to implementing any major development strategy, it is important to research the role of existing markets in local livelihoods, and assess who is likely to benefit or lose from change; the so-called vulnerability context. Such an analysis can also clarify the roles and relationships between different stakeholder groups in relation to shared use of fish and water resources. This is a key factor in the design of sustainable culture-based fisheries strategies.

Figures 54 and 55 show inland fish consumption patterns in three dry-zone villages where stocking experiments (using wild-sourced tilapia and snakehead) were conducted in small seasonal reservoirs. Results are extrapolated from a 7-day recall of household consumption over 13 months, with interviews conducted on a fortnightly basis.

Figure 55 shows that compared to comparable rice-growing countries in South-east Asia (e.g. Laos and Cambodia), even poor households in Sri Lanka appear to be far more reliant on purchasing fish (from perennial reservoirs) than harvesting aquatic animals from rice fields and water bodies. However, this finding

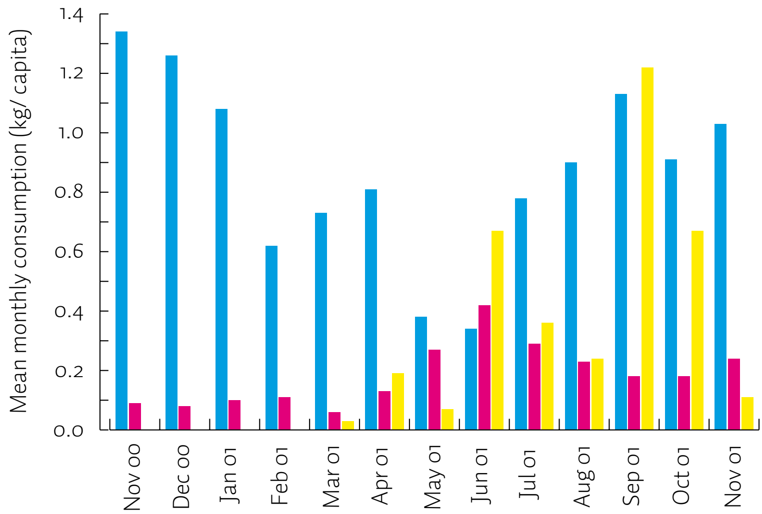


Large tilapia >150g	6.36	4.87	2.13	0.13		0.28			0.07
Small tilapia <150g	3.58	5.62	3.87	0.33	1.27	1.99	0.75	1.33	2.10
Snakehead	0.41	0.57	0.09	0.58	0.26	0.69	0.58	0.63	0.89
SIS	0.27	0.35	0.12		0.08	0.05	0.66	0.05	0.50
Snakeskin gouramy						0.01	0.07	0.03	0.83
Eels (*Anguilla* Spp.)		0.08	0.11						
Common carp	0.07	0.08	0.02					0.04	

Figure 54. Mean annual *per capita* consumption of inland fish varieties by production source in three low-caste villages participating in stocking trials, Dec 2000–Nov 2001.

still masks the seasonal importance of subsistence production from village reservoirs to the livelihoods of the poorest groups. Figure 49 shows how these villagers substitute commercial fish for their own catches between May and November, thereby making considerable indirect financial savings. Moreover, the seasonal livelihood calendar presented earlier in this manual (Figure 6) clearly shows that on-farm/off-farm employment opportunities are lowest during this dry-season period when many families struggle to maintain their basic food security. Both figures also reflect how consumption of smaller (low cost) tilapias from both production sources is one coping strategy for the poor (even being substituted for vegetables which are more costly in the dry season).

Furthermore, the poachers, frequently held accountable for the failure of community-based stocking initiatives, are most likely to come from this group. Yet analysis of the situation in Sri Lanka indicates that such activity is tolerated at low levels, and even informally reciprocated between villages. Careful thought and much imagination therefore needs to be given to how the interests of poor subsistence fishers and consumers can be improved, or at least maintained, where culture-based fisheries are implemented.



	Nov 00	Dec 00	Jan 01	Feb 01	Mar 01	Apr 01	May 01	Jun 01	Jul 01	Aug 01	Sep 01	Oct 01	Nov 01
Major irrigation system	1.34	1.26	1.08	0.62	0.73	0.81	0.38	0.34	0.78	0.90	1.13	0.91	1.03
Other village tank	0.09	0.08	0.10	0.11	0.06	0.13	0.27	0.42	0.29	0.23	0.18	0.18	0.24
Stocked village tank					0.03	0.19	0.07	0.67	0.36	0.24	1.22	0.67	0.11

Figure 55. Mean monthly *per capita* consumption of inland fish by production source in three low-caste villages post-stocking, Nov 2000–Nov 2001.

The market network for inland fish has proved very well adapted to the needs of numerous small-scale producer and traders. This is remarkable given that it has occurred with negligible institutional support. The poor are effectively excluded from newly liberalised cash crop markets in other agricultural sectors. Given this vulnerability context, the existing market mechanism must be considered first and foremost as a livelihood 'safety net' for the poor. Other benefits include:

- Equitable returns to different levels of the marketing network largely because of market space, i.e. the nature of the supply, multi-point landing and marketing of fish at tanks and their marketing mainly to dispersed rural population
- Good local demand, allows marketing chains to remain unsophisticated and accessible by the poor working on a short-term basis. This makes trading a robust livelihood option with low entry costs that don't require sophisticated support.
- Seasonal employment as fishers and traders for landless, share-croppers and agricultural labourers.
- Smaller, lower valued species marketed to the poorer and most remote communities. This reduces costs and opens opportunities to poorer traders limited to the use of bicycles.

- Opportunities for low caste, poor women in the production and marketing of small dried fish. The large market for dried fish, although not an option for 'adding value', does make salvage an option. This is important for reducing risk to producers and traders.

Culture-based fisheries must therefore be adapted to add value to the existing system, while being inclusive of those who are currently most reliant on it. For example, efforts to commoditise output through bulk production for export markets are likely to be detrimental in this instance. On the other hand, culture-based fishery systems must be able to compete locally at prices comparable to the existing tilapia fishery if they are to be sustainable. Lack of private sector incentives to produce food-fish fingerlings is also a major constraint.

Acknowledgments

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Annex I

A model questionnaire used for preliminary selection of non-perennial reservoirs for culture-based fisheries in Sri Lanka

1. Administrative district: ______
2. Divisional secretariat division: ______
3. Village administrative unit: ______
4. Village: ______
5. Reservoir: ______
6. Name and address of ______
   Farmers Organisation (FO): ______
7. Reservoir capacity/full supply area: ______
8. Acreage of the paddy fields cultivated under the reservoir:
   a. first cultivation (Yala season): ______
   b. second cultivation (Maha season): ______
9. a. Number of members in Farmers Organisation: ______
   b. If the reservoir is controlled by a small group other than the FO, the number of members in that group: ______
10. Water retention period (months): ______
11. a. Does the FO agree to start a culture-based fisheries program?
   ☐ no ☐ yes
   b. If no, can you obtain their permission?
   ☐ no ☐ yes
12. Are there aquatic weeds in the reservoir?
   ☐ no ☐ yes
13. If yes, do you agree to remove aquatic weeds whenever necessary?
   ☐ no ☐ yes
14. If you are planning to carry out a culture-based fisheries program, do you agree to establish a fisheries committee?
   ☐ no ☐ yes

15. Number of farmers who cultivate under the reservoir:

a. their own land: ______________________________

b. leased land/or other: ______________________________

16. Is the majority of the farmers engaged in the following practices other than paddy culture?

a. ☐ chena (slash-and-burn) cultivation

b. ☐ animal husbandry

c. ☐ fruit/vegetable cultivation

d. ☐ brick production

e. ☐ other

17. For fish culture, majority of the farmers

a. ☐ will agree

b. ☐ will not agree

c. ☐ don't know

18. Do you believe in any religious effect on fish culture practices?

☐ no ☐ yes

19. Possible number of farmers who would agree to actively engage in fish culture: ____________

20. Possible number of farmers with a general knowledge on fishing or fish culture: ____________

21. Fish culture can be generally considered as

a. ☐ an employment (1)

b. ☐ a nutritious or cheap food source (1)

c. ☐ an additional source of income (1)

d. ☐ a disgusting activity (0)

22. Distance from reservoir to the village: ____________________ ☐ miles ☐ km

23. Distance from reservoir to the nearest town: ____________________ ☐ miles ☐ km

24. Type of the road access to the reservoir

a. ☐ tar road

b. ☐ gravel road

c. ☐ cart trail

d. ☐ foot path

e. ☐ no path at all

25. Is reservoir within an area controlled by the Department of Wildlife or other governmental institution?

☐ no ☐ yes

26. Are there any NGOs affecting the practices associated with the reservoir?

☐ no ☐ yes

27. During the past three years, the reservoir

a. ☐ was rehabilitated

b. ☐ wasn't rehabilitated

c. ☐ was proposed to be rehabilitated in the near future