

# Results of a decade of R&D efforts on culture-based fisheries in Sri Lanka

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**Abstract:** Fisheries enhancement is defined as technical intervention in the life cycles of fish. Culture-based fisheries (CBF) development is one of the major fisheries enhancement strategies practised in inland reservoirs of Sri Lanka. The extensive availability of inland reservoirs in the country, primarily constructed for irrigation of land crops in ancient times, favours CBF development, which is essentially a development since late 1990s. Water retention period in most small village reservoirs in the country is seasonal and lasts for six to nine months in the year. CBF development in these reservoirs therefore requires fast growing fish species such as Chinese and Indian major carps. Hormone induced captive breeding of major carps in government-owned hatcheries and fingerlings rearing in mini-nurseries, maintained by rural agricultural farmers, are the sources of seed for stocking these village reservoirs.

The CBF in village reservoirs of Sri Lanka is a communal activity involving agricultural farmers without prior experience in fisheries. As such, awareness programs conducted for these farmers have facilitated establishment of CBF in small village reservoirs. The biological productivity of water bodies and socio-economic conditions of rural communities were found to vary from reservoir to reservoir. As such, successful R&D efforts were made for selection of village reservoirs suitable for CBF development, based on the biological productivity-related parameters such as reservoir morphometry, allochthonous input of nutrients through livestock farming, and socio-economic characteristics of rural communities that favour CBF. For CBF development in village reservoirs, correct timing is necessary for fingerling production to suit the monsoonal rainy season when the reservoirs get filled. Climate change impacts, which resulted in a shift in peak monsoonal rainy season were therefore identified together with possible resilience capacities of rural communities for sustainability of CBF.

Dissemination of research findings through various means such as production of a documentary film, publication of a monograph which was translated to several regional languages, and holding a series of regional workshops were instrumental for CBF development at the regional level. The Asian Development Bank funded Aquatic Resources Development and Quality Improvement Project, which contained a significant component for CBF development in inland reservoirs of Sri Lanka, has also been facilitated by R&D efforts mentioned above. The recent efforts to develop CBF in Sri Lanka include establishment of profitable CBF with effective co-management in selected minor perennial reservoirs, and the use of *Macrobrachium rosenbergii* post-larvae for CBF in many inland reservoirs.

**Key words:** Culture-based fisheries, Chinese carps, Indian carps, Inland reservoirs, *Macrobrachium rosenbergii*.

## Introduction

In the wide array of fisheries enhancement strategies, the common feature is human intervention in the life cycle of the aquatic organism that is used for fisheries enhancement (Lorenzen et al. 2001), and “culture-based fisheries” and “capture-based aquaculture” are two major terminologies in this context. The term “culture-based fisheries” (FAO 1997; De Silva 2003) is used to define the fisheries enhancement strategies that involve release of hatchery-reared fingerlings to the wild for subsequent recapture after a reasonable growth period. As such, this is essentially “aquaculture-driven.” On the other hand, “capture-based aquaculture” involves capture of cultured organisms from the wild and rearing them in various aquaculture systems such as cages (Ottolenghi et al. 2004) and this enhancement strategy is therefore “fishery-driven.”

As culture-based fisheries (CBF) are aimed at stocking of different species which are able to optimally utilise available food niches, they often share features of polyculture (Bardach et al. 1972). Also CBF comes under the realm of aquaculture because globally in all CBF strategies, ownership is defined (De Silva 2003). The potential for CBF in small, village reservoirs of Sri Lanka was first recognised by Mendis (1965, 1977). Nationally, this is of particular importance due to the fact that Sri Lanka

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has a long tradition of irrigation water management in reservoirs some of which dating back to the first century AD.

Although in general, irrigation systems are recognised as common pool resources, supplying water for agricultural production (Meinzen-Dick and Bakker 1999), in the Sri Lankan context, irrigation water resources do not fall into open access property regime. Irrigation of agricultural lands is essentially based on pre-planned schedules and water is not freely available on demand to the farmers. As such, CBF can be incorporated as a community-based activity during the planning stage of an irrigation schedule for the two cultivation seasons, in a calendar year, in the command areas of each reservoir. These community-based water management strategies and CBF in village reservoirs are facilitated by the Department of Agrarian Development and the National Aquaculture Development Authority of Sri Lanka (NAQDA) respectively, under the legal provisions of *Agrarian Development Act of 2000*.

Due to extensive availability of lentic water bodies in Sri Lanka (Table 1), there is a promising potential for inland fisheries development in the country that favours CBF. Water retention period in most small village reservoirs in the country is seasonal and lasts for six to nine months. CBF development in these reservoirs therefore, requires fast growing fish species such as Chinese and Indian major carps. Hormone induced captive breeding of major carps in government-owned hatcheries and fingerlings rearing in mini-nurseries, maintained by rural agricultural farmers, are the sources of seed material for stocking in the village reservoirs.

In the 1980s, fisheries authorities made efforts to develop CBF in non-perennial reservoirs in the dry zone of Sri Lanka (Thayaparan 1982; Chandrasoma and Kumarasiri 1986). However, in this effort lack of a proper selection method for the identification of suitable reservoirs was a major set-back for developing CBF in non-perennial reservoirs in Sri Lanka. Due to dense distribution of reservoirs in Sri Lanka, it is impossible and impracticable to visit individual reservoirs and observe their suitability

for CBF. Furthermore, politically inspired policy decision to discontinue state patronage to inland fisheries and aquaculture development between 1990-1994, also had a detrimental impact on the inland fishery developments of the country (Amarasinghe 1998). Realising the national need for sustainable development of inland fisheries in Sri Lanka, Deakin University, Victoria, Australia, University of Kelaniya, Sri Lanka and NAQDA developed a collaborative research project under the auspices of Australian Centre for International Agricultural Research (ACIAR) for scientific management of reservoir fisheries of Sri Lanka, a major part of which was sustainable development of CBF. In this chapter, R&D efforts of CBF development in Sri Lanka under the ACIAR-funded project, and subsequent CBF development efforts performed under the Asian Development Bank-funded “Aquatic Resources Development and Quality Improvement Project” (ARDQIP) are reviewed.

Accordingly and primarily, this paper reviews the previous major findings (De Silva et al. 2004; Jayasinghe et al. 2005, 2006; Wijenayake et al. 2005, 2007; Jayasinghe and Amarasinghe 2007; Jarchau et al. 2008; Kularatne et al. 2008, 2009; Amarasinghe and Nguyen 2009; Pushpalatha and Chandrasoma 2010). Furthermore, it is believed that the results of the R&D on CBF in Sri Lanka will have much relevance to developing CBF in other developing countries in the region, thereby contributing to the fish supplies and the socio-economic wellbeing of rural communities in particular.

## Influencing strategies for CBF development

After the revival of state patronage for inland fisheries and aquaculture development in the country in 1994, steps were taken to establish NAQDA and to rehabilitate state-owned fish hatcheries which were responsible prior to 1990, for induced breeding and fingerling rearing of Chinese and Indian major carps, and stocking of inland reservoirs. As small village reservoirs are managed by the rural institutions called farmer organisations (FOs),

**Table 1. The estimated surface area of lentic water bodies of Sri Lanka. NA - Not available (Source: Jayasinghe and Amarasinghe, in press).**

Type	Number	Area (ha)	Percent (%)
Major irrigation reservoirs (ancient)	72	70,850	34.4
Medium-scale reservoirs (ancient)	160	17,001	8.3
Minor irrigation reservoirs (ancient)	> 10,000	39,271	19.1
Floodplain lakes (natural)	NA	40,000	19.4
Upland hydroelectric reservoirs (recent)	7	8,097	3.9
Mahaweli multipurpose system of reservoirs (recent)	6	13,650	6.6
Other (e.g. aesthetic reservoirs, water supplying reservoirs, village ponds)	NA	17,023	8.3
Total		205,892	100.0

which have legal power under the *Agrarian Development Act*, these rural institutions were chosen to implement influencing strategies for CBF development with a view to leading members of FOs across boundaries. Meetings of FOs before the agricultural cultivation period (“Kanna Meeting”), under the supervision of Agrarian Research and Production Assistants (ARPAs) employed by the Department of Agrarian Development. These meetings provided an opportunity to discuss and place before the FOs about the possible nutritional and financial benefits that would be generated from CBF in their reservoir if they were to embark on CBF. This approach was further developed by NAQDA and the aquaculture extension officers of NAQDA, closely worked with the members of FOs to develop an “entrepreneurship plan” for CBF development in each village reservoir.

### Efforts for selection of suitable non-perennial reservoirs for CBF development

The general practice adopted for selecting reservoirs for CBF development was ineffective because it was entirely based on the ad-hoc requests made by ARPAs. As such, effective procedures for selection of suitable village reservoirs for CBF development were needed for its sustainability in the country especially due to limitations in terms of manpower and funding for extensive surveys for selecting reservoirs suitable for CBF development. However, ‘human capital’ in the rural institutions (i.e. FOs) has a high potential to be mobilised for CBF development. The efforts to define a better practice model should include both biological aspects related to productivity of water bodies and socioeconomic aspects of rural communities (De Silva et al. 2006).

#### Limnological aspects

Carlson’s trophic state index (TSI) is a diagnostic approach (Carlson 1977), which in general, is used to monitor status of lentic waters. Carlson’s TSI in non-perennial reservoirs were determined as TSI (SD), TSI (Chl) and TST total phosphorus) according to the following definitions (Jayasinghe et al. 2005).

$$\text{TSI (SD)} = 60 - 14.41 \ln \text{Secchi disk (metres)}$$

$$\text{TSI (Chl)} = 9.81 \ln \text{chlorophyll-a (mg/m}^3\text{)} + 30.6$$

$$\text{TSI (TP)} = 14.42 \ln \text{total phosphorus (mg/m}^3\text{)} + 4.15$$

The relationships between the three definitions of TSI (Table 2; Carlson 1977) can be used to determine the conditions of the non-perennial reservoirs. Jayasinghe et al. (2005) observed that in non-perennial reservoirs of Sri Lanka  $\text{TSI (TP)} = \text{TST (SD)} > \text{TSI (SD)}$  showing non-algal particles dominate light attenuation.

Jayasinghe et al. (2005) further showed that CBF yields were positively correlated to chlorophyll-a content. In non-perennial reservoirs with similar trophic characteristics, CBF yield could be predicted from shoreline/reservoir area ratio (Jayasinghe et al. 2006). In rural villages of dry zone of Sri Lanka, buffalo and cattle keeping is one of the economic activities. Nutrient enrichment in village reservoir through cow dung also positively influence CBF yields (Jayasinghe and Amarasinghe 2007).

#### Biological and technological aspects

In village reservoirs, which do not completely dry up during the dry season, carnivorous fish species such as *Channa striata*, *Glossogobius giuris* are drawn from the associated river basins. Naturally in such reservoirs, stocked fish fingerlings are vulnerable to predatory pressure, resulting in low returns from the CBF efforts (Wijenayake et al. 2005). De Silva (1988) suggested that this could be prevented by stocking large-sized (>10 cm) fingerlings as predator-prey relationship is usually size-dependent. Also, our experience is that when freshwater prawn (*Macrobrachium rosenbergii*) post-larvae are stocked, night stocking (after 19:00 hr) ensures higher survival. This might be due to the reason that prawn post-larvae can move to the bottom of the reservoir so that they can avoid predation by fish species such as *Rasbora daniconius* and *R. cavarii*, which are essentially visual feeders in the water column during twilight periods of the day (De Silva et al. 1996; Weliange et al. 2006).

**Table 2. Relationships between three definitions of TSI showing status of reservoir limnology.**

Relationship	Condition
$\text{TSI (Chl)} = \text{TSI (TP)} = \text{TSI (SD)}$	Algae dominate light attenuation
$\text{TSI (Chl)} > \text{TSI (SD)}$	Large algae particles dominate
$\text{TSI (TP)} = \text{TST (SD)} > \text{TSI (SD)}$	Non-algal particles dominate light attenuation
$\text{TSI (SD)} = \text{TSI (Chl)} > \text{TSI (TP)}$	Phosphorus limits algal biomass
$\text{TSI (SD)} = \text{TSI (Chl)} < \text{TSI (TP)}$	Factors other than phosphorus limit algal biomass

Species combination of stocked fingerlings is also an important aspect in CBF because optimal utilisation of food resources in the water body is a key to achieve optimal harvests from polyculture systems (Bardach et al. 1972). Although there had not been many scientific studies on this aspect, generally the species combination used was 30% common carp and mrigal, 30% bighead carp/catla; 30% rohu and 10% Nile tilapia/freshwater prawn (Wijenayake et al. 2005, 2007).

In non-perennial reservoirs, the relationship between stocking density (SD) and CBF yield showed a second order curve (Wijenayake et al. 2005), conforming to those that were reported elsewhere (e.g., Bangladesh- Hasan and Middendrop 1998; India- Sugunan and Katiha 2004). Accordingly, the optimal stocking density was determined to be 3,500 fingerlings per ha (Wijenayake et al. 2005). Here, it must be noted that effective area for CBF planning was considered as 50% of the area at full supply level (FSL) because extents of non-perennial reservoirs at FSL during the rainy season gradually shrink to almost zero during the dry season.

### Socio-economic aspects

The community meeting of FOs held at the beginning of the cultivation season, the Kanna meeting, is meant for planning agricultural activities through collective decisions. At these meetings, FOs also make decisions whether CBF activities should be incorporated in the agriculture-related economic activities. As these community-based initiatives are backed by the legal provisions of *Agrarian Development Act of 2000*, in most instances, FOs establish Aquaculture Management Committees (AqMCs), which are responsible for stocking fish fingerlings, guarding the stocked fish, harvesting and marketing. The members of AqMCs arrive at agreements with FOs on sharing of CBF profit between the AqMC and FO. In many instances, a levy of about 5% of the net profit is paid to FOs. The group size of AqMC generally varied between 5 and 20. There are rare instances where the entire FO acts as the AqMC because all members of FO take part in the CBF activities. After payment of the levy to the FO, the profit is equally shared by the members of AqMC.

Kularatne et al. (2009) have shown that communities with small group size in AqMCs with satisfactory participation in group activities and those belong to same caste expressed high 'willingness to pay' for CBF activities. Also socioeconomic homogeneity with regard to kinship and political ideology of the farming communities as well as education level and good leadership qualities of group members in AqMCs are found to have a positive influence on the attitudes towards adoption of CBF in village reservoirs (Kularatne et al. 2008). As such, socioeconomic characteristics in rural agricultural

communities are needed to be considered for selecting suitable reservoirs for CBF development. At a national workshop on participatory approaches to reservoir fisheries management, Jarchau et al. (2008) presented a scheme of decision making to select suitable reservoirs for CBF development taking into account both technical feasibility assessment (Figure 1) and social feasibility assessment (Figure 2).

### Multi-criteria decision making

For selection of suitable reservoirs for CBF development, several criteria should be considered such as water quality parameters, catchment land-use characteristics, socioeconomic factors and marketing aspects, under which there are several sub-criteria with varying relative importance. As such, a multi-criteria decision making

**Figure 1. Decision flow for the technical feasibility assessment of non-perennial reservoirs (Jarchau et al. 2008).**

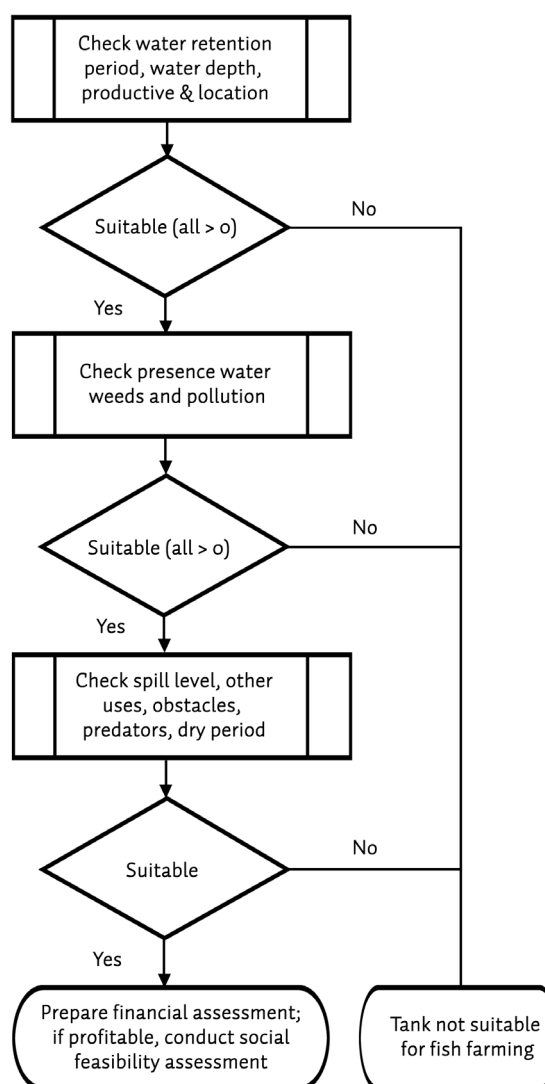
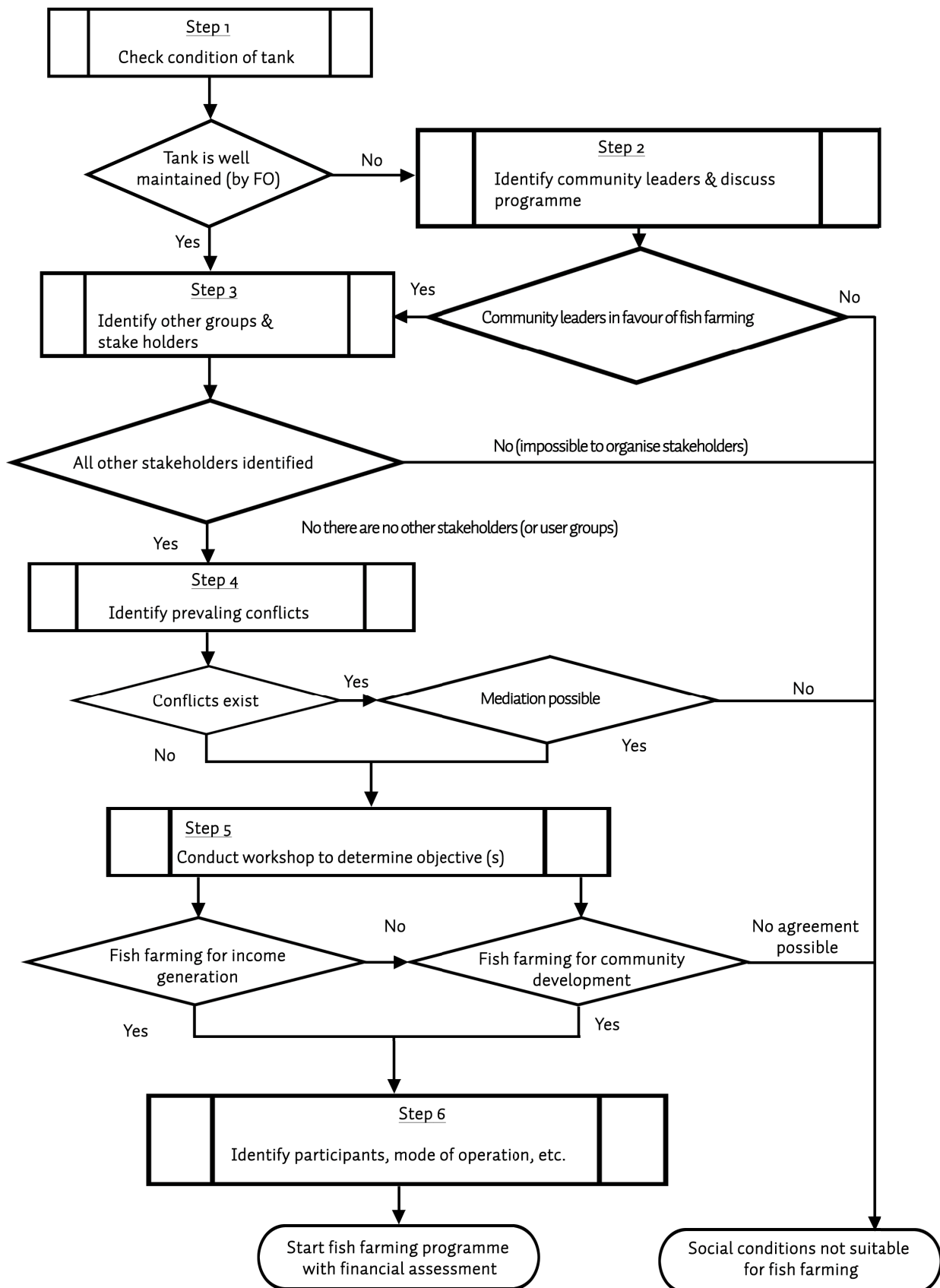


Figure 2. Decision flow for the social feasibility assessment of non-perennial reservoirs (Jarchau et al. 2008).



procedure known as Analytic Hierarchical Process (AHP; Satty 1977) was employed (De Silva et al. 2004). This approach equates sets of heterogeneous criteria into a common denominator, and as such, it is a powerful decision making tool for selection of reservoirs for CBF based on their ranking through relative weighting of multiple criteria.

### Other initiatives for CBF development

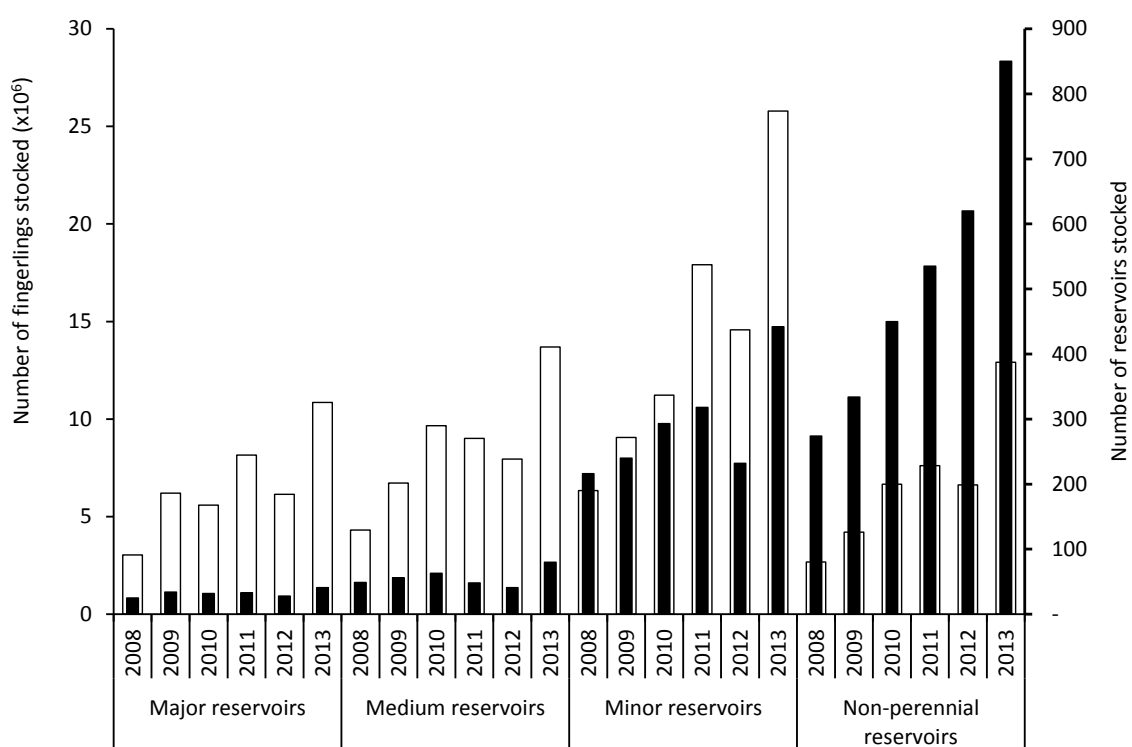
After implementation of the Asian Development Bank-funded ARDQIP during 2004-2007, many initiatives have been taken for the CBF development in Sri Lanka. They included infrastructure development in state-owned fish breeding centres, capacity building in through training field officers in the inland fisheries and aquaculture sector, setting-up of an information system for national inland fisheries and aquaculture which would include more accurate recording of fisheries and aquaculture production data, and establishment of mini-nurseries for fingerling rearing through community participation.

### Establishment of mini-nurseries for fry to fingerling rearing

As stocking of inland reservoirs of different kinds is a regular fisheries enhancement strategy practised by fisheries authorities of Sri Lanka, availability of sufficient of fingerlings for stocking non-perennial reservoirs at the correct time is a major constraint to CBF development in the country. When fingerlings are required for stocking one category of reservoir (e.g., minor perennial reservoirs), fingerling requirement for CBF development in non-perennial reservoirs is severely constrained due to their limited supply (Figure 3).

Under the ADB-funded ARDQIP, this issue had been addressed and there were initiatives to establish mini-nurseries through community-based organisations (CBOs) to fulfil the demand for fingerlings for CBF. Through this initiative, initial capital investment was borne by ARDQIP on the condition that CBOs must pay back the total amount in 60 instalments to NAQDA (Anon. 2006). At present, there are about 29 mini-nurseries in different parts of the country. They have been established by rural community-based organisations, mainly AqMCs. Almost all these mini-nurseries are established as earthen pond systems, for which technical advice was provided to CBOs by NAQDA. Fish fry purchased from fish breeding centres of NAQDA

**Figure 3. Number of reservoirs of different categories and number of fingerlings stocked during 2008-2013 (Drawn from the data reported at <http://www.fisheries.gov.lk/content.php?cnid=ststc>). White bars – number of fingerlings stocked; dark bars – number of reservoirs stocked.**



are reared up to fingerling size in these mini-nurseries, which in turn are sold to CBF farmers. As the profit that the owners of mini-nurseries can earn is very significant, this strategy is bound to continue. The total number of non-perennial reservoirs stocked in 2013 was 850 (Figure 3), which is approximately 7 % of total number of small village reservoirs in the country. As such, opportunities exist for further development of CBF in small village reservoirs of Sri Lanka.

## Freshwater prawn stocking

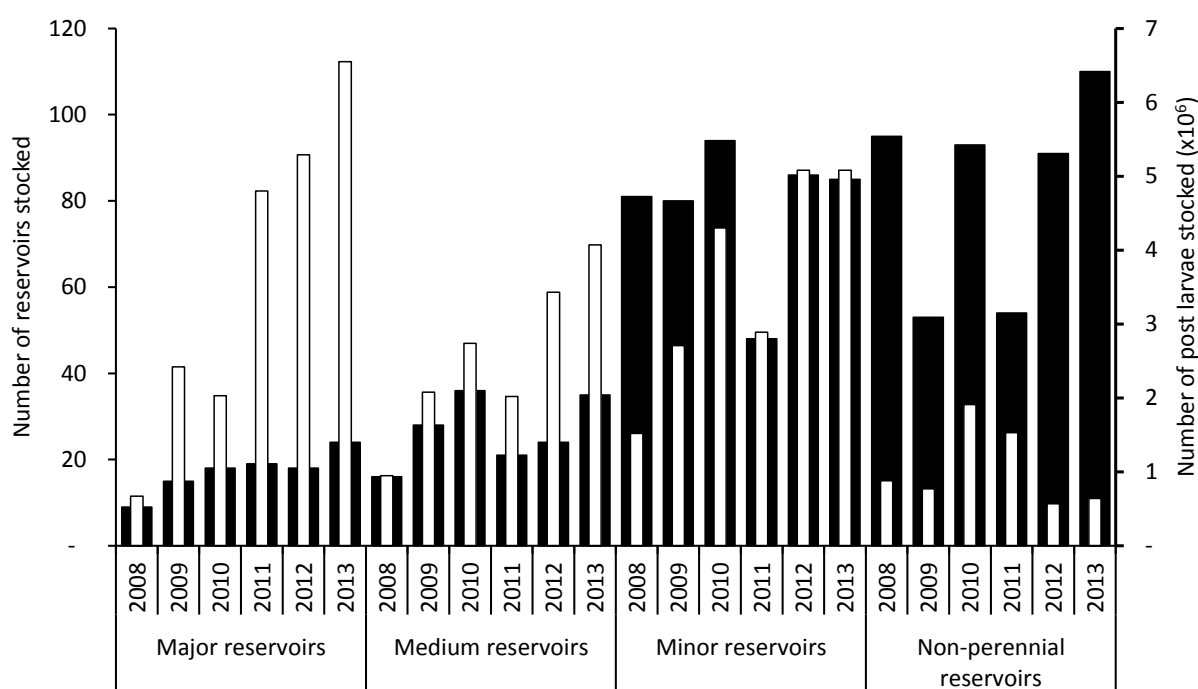
NAQDA's freshwater prawn hatchery, established in 2008 at Kahandamodara in southern Sri Lanka under the assistance by FAO, has a production capacity of 17 million post larvae per year. Aquaculture technology of *M. rosenbergii* is however, not yet well developed (in more accurate terms, well-developed technology elsewhere

has not yet been effectively transferred) in Sri Lanka and as such, there is an over-supply of *M. rosenbergii* post larvae from the NAQDA's hatchery.

Freshwater prawn post larvae were therefore stocked in different kinds of reservoirs and the total extent of reservoirs of various kinds and number of post larvae stocked are shown in Figure 4. As mentioned previously, night stocking was more effective for achieving high returns of CBF based on *M. rosenbergii*.

The stocking data and reported yields of *M. rosenbergii* in different types of reservoirs in Sri Lanka during 2012 (Table 3) indicate that there is potential for incorporating freshwater prawn into CBF development in the country. Jutagate and Rattanachai (2010) reported that in Pak Mun reservoir (a run-of-river type reservoir of about 185 km<sup>2</sup> surface area) in Thailand, stocking of 2 million post larvae of *M. rosenbergii* resulted in a yield of 3 kg ha/yr and by stocking 40 million post larvae in 2003, a yield of 11.5 kg ha/yr was achieved. These values show that

**Figure 4. Number of reservoirs of different categories and number of freshwater prawn post larvae stocked during 2008-2013. White bars – number of fingerlings stocked; dark bars – number of reservoirs stocked. (Drawn from the data reported at <http://www.fisheries.gov.lk/content.php?cnid=ststc>).**



**Table 3. Stocking densities and annual yields of freshwater prawn in different types of reservoirs during 2012 (Source: Asoka 2014; ranges are given in parentheses).**

Category	Stocking density (number of post larvae/ha)	Yield (kg/ha)
Major reservoirs (>750 ha)	158.2 (46.9 – 297.4)	3.1 (0.02 – 22.8)
Medium reservoirs (200-750 ha)	250.5 (65.0 – 830.2)	5.5 (0.08 – 70.2)
Minor reservoirs (<200 ha)	757.3 (260 – 2600)	17.6 (0.2 – 143.3)



although stocking densities were very low, reasonably high yields of freshwater prawns were achieved in this Thai reservoir. In Sri Lankan reservoirs, fishers do not use special fishing methods to catch freshwater prawns but they are caught as by-catch in gillnets targeting fin fish species. It would therefore be possible to introduce horizontal cylindrical traps (Deap et al. 2003) for catching *M. rosenbergii* in reservoirs where they have been stocked, which might increase freshwater prawn yields in reservoirs. Although the freshwater prawn yield was much lower than finfish yields in CBF activities, there were obvious financial benefits to the fishers because of high farm-gate price of freshwater prawn (SLR 570 – 705) compared farm-gate price of SLR 150-200 for finfish species in CBF yields.

### CBF in minor perennial reservoirs

As fingerlings are required for stocking in non-perennial reservoirs only after the peak rainy period in November-January in the dry zone of Sri Lanka, those which are produced in mini-nurseries during other periods can be used for CBF development in other types of inland water bodied such as minor perennial reservoirs. In 2003, NAQDA initiated through ARDQIP, a pilot-scale programme to introduce CBF in minor perennial reser-

voirs (<250 ha), where only subsistence level fisheries existed. Accordingly, in 15 minor perennial reservoirs, CBOs were formed and members were given training on basic aspects of entrepreneurship planning such as leadership, simple accounting, book keeping etc., together with aspects of community-based management of CBF.

The stocking density in CBF in minor perennial reservoirs ranged from 146 fingerlings/ha to 2780 fingerlings/ ha (Pushpalatha and Chandrasoma 2010). Unlike in non-perennial reservoirs, where harvesting is done at once during the dry season, CBF harvesting in minor perennial reservoirs is a year-round activity using gillnets of mesh sizes ranging from 8.5 to 20 cm. Before introduction of CBF in minor perennial reservoirs, mean annual fish yield was 57.3 kg/ha, with *Oreochromis niloticus* being the most abundant species forming over 80 % of the landings. However, after introduction of CBF, annual fish yield increased up to 208 kg/ha and *C. catla*, *L. rohita* and *C. carpio* formed major proportions of the landings. The contribution of *O. niloticus* to the landings reduced to 47.4 % (range 19.7- 66.5 %) (Pushpalatha and Chandrasoma 2010; Amarasinghe 2010).



Harvesting of fingerlings in a fry-to-fingerling rearing facility. Note that women of the community are taking part in the activity.



## Co-management

Co-management is essentially the sharing of responsibilities of decision-making and responsibility for the management of resources between the community (local fishers) and government centralised management (Pomeroy and Berkes 1997). According to Brown et al. (2004), for successful co-management there are four pillars as follows:

- 1) An enabling policy and legal framework.
- 2) The participation and empowerment of communities (and other users).
- 3) Effective linkages and institutions.
- 4) Resources – a resource worth managing and the people and money to do it.

The CBF development strategies in Sri Lanka consist of these characteristics. As shown by Amarasinghe and Nguyen (2009), there are legal provisions to develop CBF in inland water bodies of the country under the *Agrarian Development Act* of 2000. Also, CBF development is a high priority area of fisheries development agenda of the country (Anon. 2007).

CBF in village reservoirs are conducted by FOs (agrarian communities) rather than fishers. In medium and major reservoirs, CBF is practised by fishers, who are also organised into fisheries management societies. Community-based aquaculture (for fingerling rearing in mini-nurseries) is also within the organisational mandate of FOs, whenever a farmer community decides to adopt it. The FOs are established under the *Agrarian Development Act* of 2000. The legal provisions in this Act facilitate empowering communities. The residents of a village involved in agriculture are essentially members of FOs. The small village reservoirs, whose command areas are less than 80 ha, come under the jurisdiction of



Fingerlings at a mini fry to fingerling rearing facility ready for transportation to a water body for stocking.



Village livestock are encouraged to use the water bodies to enhance fertility and hence overall fish yield.



A harvest being transported to the market.

**Table 4. Selected examples of rural welfare activities carried out by CBF committees.**

Reservoir	Major rural welfare activities
Galwale Wewa	Funds for maintaining public well; SLR 5,000 donated for construction of pagoda in village Buddhist temple; Providing fish for village household occasions such as weddings and funerals free of charge.
Meegas Wewa	An accumulated electricity bill of the village temple over a long period was paid by the aquaculture committee.
Pahala Sandanamkulama Wewa	CBF income is used for maintaining and rehabilitation of reservoir and canals; The agreement is that the aquaculture team must provide 60% of the fish harvest to the farmer organisation.
Mataluwawa Wewa	Organised educational tours for farmers, alms-giving ceremonies for Buddhist monks, and a felicitation programme for senior farmers.

Department of Agrarian Development and those which have irrigable area greater than 80 ha are under the control of Irrigation Department.

Divisional Agriculture Committees (DvACs) are the major district-level institutions, which are responsible for facilitating agricultural development. There are monthly meetings of DvACs and the Divisional Secretary presides the meeting. District Officer (DO) of Department of Agrarian Development, irrigation engineer, Samurdhi officer (government officer responsible for implementing state-sponsored poverty alleviation programmes), “Grama Niladhari” (village-level administrative officer), aquaculture extension officer are the middle level government officers in this committee. Agrarian Research and Production Assistants (ARPAs), who work under the supervision of DO, are the major contact persons of FOs. The officer bearers of FOs and ARPAs are also participants of monthly meetings of DvAC (Amarasinghe and Nguyen2009; Amarasinghe 2010). These institutional linkages provide a positive environment for introduction of co-management strategies for CBF.

Extensive availability of village reservoirs, which are not used for fisheries development, willingness of agricultural communities to take up CBF, and well-established CBOs for operating mini-nurseries for fingerling rearing are the resources prevailing for CBF development in the country. In some reservoirs, CBF committees have

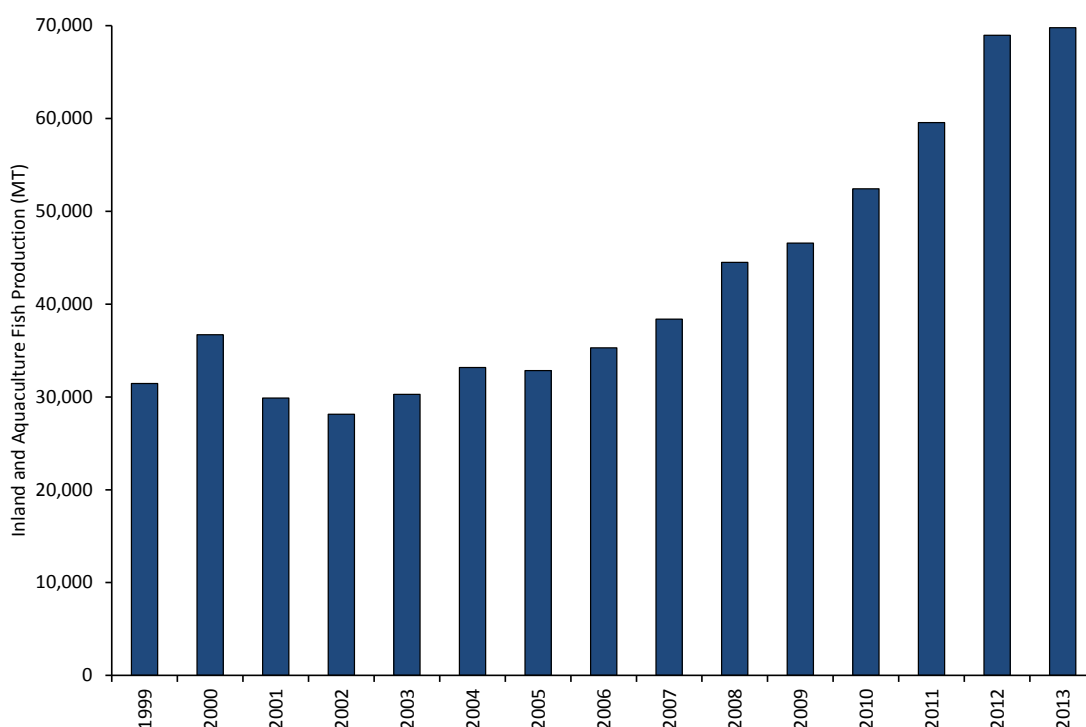
invested money to establish computer-assisted data bases for stocking harvesting, marketing and welfare fund mobilisation, due to promising financial benefits from CBF.

Members of CBF committees become partners of community-based enterprises and they invest in the community owned venture. Also, members share the financial benefits of CBF activities on an agreed basis, which ensures sustainability of the strategy. These features in CBF strategies in Sri Lankan reservoirs indicate potential for establishing co-management effectively. In fact, such co-management strategies exist in several reservoirs (Chandrasoma et al. this volume).

### Benefits of CBF to rural development

The benefits CBF to rural communities associated with reservoirs where ACIAR-funded project(s) for CBF development were monitored few years after conclusion of the project. In many villages, due to elevated income through CBF among the members of aquaculture committees, there were significant contributions to develop public utilities. Some examples are summarised in Table 4. These rural welfare activities performed by CBF committees brought good reputation for the CBF.

**Figure 5. Annual inland fisheries and aquaculture production in Sri Lanka (1999–2013). Drawn from the data reported at [http://www.naqda.gov.lk/inland\\_Aquaculture.php](http://www.naqda.gov.lk/inland_Aquaculture.php).**



Dissemination of research findings through various means such as production of a documentary film, publication of a monograph (De Silva et al. 2006) which was translated to several regional languages, and holding a series of regional workshops were instrumental for CBF development in the regional level.

## The gains from CBF in Sri Lanka

It is ironic that a concept that was first suggested by Mendis (1965) for small water bodies in Sri Lanka is gaining a firm foothold in Sri Lanka inland fisheries, and for that matter elsewhere in the region. The evidence that the R&D efforts are best exemplified by the following facts and figures.

- A science based objective method for selecting non-perennial and perennial water bodies for CBF practices, thereby avoiding waste of resources and effort; these science based methods, with suitable modifications could be adopted for other tropical countries that wish to embark on CBF.
- After implementation of CBF large scale in village reservoirs systematically in early 2000s, annual inland fisheries and aquaculture production has significantly increased from about 28,000 MT in 2002 to about 69,800 MT in 2013 (Figure 5).
- The expansion of CBF development is evident from the significant increase of number of fingerlings stocked from 2.67 million in 274 non-perennial reservoirs in 2008 to 12.90 million in 2013 in 850 reservoirs (Figure 3). During this period cumulative extent of non-perennial reservoirs utilised for CBF development increased from 2,677 ha in 2008 to 11,475 in 2013 (<http://www.fisheries.gov.lk/content.php?cnid=ststc>).
- The gradual success of CBF based on the application of science and improved community organisation sparked off an ancillary sector of fry to fingerling rearing bringing about employment opportunities and economic gains to rural households.
- As detailed out by Chandrasoma et al. (the current volume) CBF has been successfully extended to medium and major perennial reservoirs that have resulted in large increases in fish yield, and consequent gains in the socio-economic status of fishers and related communities.
- Increased fish yields through CBF activities also have expanded the associated value and market chains benefiting rural communities through added employment opportunities.

## The way forward

Based on case studies in Southeast Asian countries, Lorenzen (1995) has shown that density-dependent growth and size-dependent mortality of stocked species have significant impacts on CBF yields. As such, application of similar approaches in CBF in Sri Lanka will be useful to optimise CBF yields.

As CBF development is carried out in reservoirs which have been constructed primarily for irrigation, being a secondary use, CBF development should be carried out without compromising primary uses of water bodies. As such, synergy between water management related to downstream activities and fisheries enhancement should be ensured for sustainability of CBF. At the full scale of CBF development in Sri Lanka, there will be a glut of fish in the market so that it would be timely to develop post-harvest technology for value addition.

De Silva (2003) mentioned that CBF is an environmentally friendly form of aquaculture. However, it would be possible to acquire global recognition for CBF through implementation of the FAO code of conduct for responsible fisheries through an ecosystem approach to fisheries and aquaculture. This will also help achieving balance between conservation and fishery resources enhancement.

## Conclusions

Being a country with extensive availability of freshwater reservoirs most of which a very small (< 50 ha) village irrigation reservoirs, not capable of supporting any commercial scale fisheries through natural recruitment, there is a high potential for the development of culture-based fisheries (CBF). The efforts made in 1980s to develop CBF in these water bodies were disrupted due to lack of proper scientific approaches for selection of suitable reservoirs. Under an R&D project conducted through financial assistance from Australian Centre for International Agricultural Research (ACIAR), a best practice approach was developed using multi-criteria decision making procedure. Several middle level scientists and academics were trained under this research project and the aquaculturists of National Aquaculture Development Authority were benefitted through such training. The development activities mainly on the technical aspects of Asian Development Bank funded Aquatic Resources Development and Quality Improvement Project (ARDQIP) which contained a major component for CBF development were considerably facilitated due to the involvement of trained staff under the ACIAR project.

Social mobilisation and development of entrepreneurship plan among rural communities under the ARDQIP, ensured sustainability of CBF in many reservoirs.

ARDQIP was also instrumental for establishing mini-nurseries for rearing of fingerlings of Chinese and Indian major carps, pilot scale CBF development in minor perennial reservoirs and establishment of computer-based effective data recording systems. Recent attempts at stocking *M. rosenbergii* post larvae in inland reservoirs as part of CBF contributed to significant elevation of rural income. In many rural communities, there had been spectacular trends that part of the profit earned by CBF had been mobilised for various welfare activities in the village. Opportunities exist for establishment of effective co-management strategies for CBF and in fact, such co-management procedures are in place.

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