Culture-based fisheries: Why, what, where, how and for whom?

Sena S. De Silva

School of Life & Environmental Sciences, Deakin University, Warrnambool, Victoria 3280, Australia.

Abstract: In the wake of increasing population and rising average per caput consumption of food fish and a plateauing off of the traditional food fish supplies there is an urgent need to close the increasing gap between supply and demand. It is generally acknowledged that aquaculture would increasingly contribute to closing this gap. Aquaculture production is still and likely to continue to be dominated by freshwater finfish production well into the foreseeable future, concentrated in developing countries.

However, increasing intensification of inland aquaculture is confronted with resource limitations such as land and water, and biological inputs such as feeds and consequently other plausible alternatives have to be explored. One such alternative is to utilise small and medium sized water bodies, which are estimated to be found in great abundance in developing countries of the tropics (e.g. estimated around 67 x 10^6 ha in Asia alone). These are mostly incapable of supporting even subsistence fisheries through natural recruitment, but could be utilised, secondarily, for culture-based fisheries development (CBF).

CBF is essentially a stock and recapture strategy, where the stocked fish feed and grow on naturally produced food resources, and which are most effective when communally managed. The returns from CBF could be very significant in terms of nutritional as well as monetary benefits to the communities.

In this presentation the relevant background information on food fish needs and the ways and means of introducing CBF practices in inland waters are dealt with. The importance of this environmentally "friendly" practice to enhance food fish production in rural communities are emphasised and the way such practices need to be conducted for optimal benefits are discussed.

Key words: *Culture-based fisheries, small water bodies, rural communities, food fish needs.*

Introduction

There is a general consensus that the current world population of 7.1 billion will increase to 9.5 billion by 2050, with the bulk of the increases occurring in the developing world. The commonly asked question in many a forum is 'can the world provide sufficient food or is our planet capable of producing sufficient food to cater to the increasing population?' The projected food demand will require a substantial increase in food production, nearly a 70% increase from the present level. This entails, for example, an increase of nearly 1 x 10^9 tonnes of cereals and 200 x 10^6 tonnes of meat (FAO 2009). The subject of meeting the food needs in 2050 for a projected population of 9.5 billion has received much attention from numerous sources, and from various viewpoints (e.g. FAO 2009; Hanjra and Qureshi 2010; Godfray et al. 2010). Clay (2011) identified eight steps that, taken together, could enable farming to feed 10 billion people and keep Earth habitable. WFC (2011) addressed the issue on aquaculture, fisheries poverty and food security.

Fish is a significant component of the diet of many around the world, particularly in developing countries, and most significantly in Asia. This is depicted by the fact that the average per caput consumption in Asia is 27-29 kg/yr as opposed to 17-19 kg/yr in the world (FAO 2011). Moreover in certain Asian countries, such as Cambodia, with a per caput consumption of 52.4 kg/year, fish account for nearly 80% of the animal protein intake.

Fish consumption has been rising in the world. However, it is acknowledged that the traditional food fish supplies, primarily the marine capture fisheries have at best plateaued, around 100 million t/yr. Forecasts for marine capture fisheries remain rather grim with over 58% of the stocks collapsed and overfished, and another 33% fully exploited (Froese et al. 2012) resulting in a widening gap between demand and supply of food fish. It is reckoned that this gap can be narrowed through aquaculture development.

Aquaculture has come to the forefront of food fish production in the last three decades and has enabled food fish supplies to be of farmed dominance like our other staples (De Silva 2012). The aquaculture sector, with a marked developing country dominance, in particular in the Asia-Pacific region and China, has continued to grow at a steady rate of around 6% per annum, the highest rate of growth recorded for any

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primary production sector (Subasinghe et al. 2009). The great bulk of this growth surge in aquaculture has been through a gradual increase in the land area used for aquaculture, expansion of cage culture in existing inland water bodies and in the sea together with an increasing degree of intensification of the culture practices; the latter achieved through improved water management, improved feeds, disease control, genetic improvement and the like. Overall, however, aquaculture production occurs predominantly in fresh- and brackish waters (FAO 2011).

Although growth of the aquaculture sector has been relatively consistent over the last two decades or so, there are many challenges that confront it. Intensification of aquaculture leads to environmental degradation, increased demand on resources- physical and biological, and also raises ethical issues regarding the very high proportion of use of certain biological resources such as fish meal and fish oil (Tacon et al. 2010). More often than not, when considering the challenges of feeding 9.5 billion people the issues of competition for land, water and energy and the over exploitation of capture fishery resources are often raised (Hanjra and Qureshi 2010; Godfray et al. 2010; Cao et al. 2015). The general consensus is that these issues are further exacerbated by impending climate change impacts on aquaculture, particularly in respect of specific, productive farming systems (De Silva and Soto 2009; Leung and Bates 2013; Nguyen et al. 2014). In the above context one has to accept that aquaculture intensification cannot go unabated, and the sector has to explore other potential and plausible means of increasing food fish production.

Why CBF

It is thought that the dilemma that confronts strategists in determining ways of narrowing the gap between supply and demand for food fish needs for a growing population is far from straight forward. Further, intensification and opening up new areas (land) for aquaculture development, particularly in tropical Asia, the mainstay of modern aquaculture are unlikely to be the primary thrust in to the foreseeable future, but other alternatives, including expansion in mariculture, are needed and possible (Klinger and Naylor 2012). On the other hand, utilisation of the vast acreages of small water bodies may also be an acceptable CBF development strategy for most nations and governments for a number of reasons. These water bodies, estimated at nearly 66.7 million ha in Asia alone (FAO 1999), may be natural and quasi natural, manmade, perennial and or seasonal, retaining water for six to eight month in a calendar year. The potential of CBF as an opportunity to increase food fish availability and nutrition among rural communities have been highlighted previously (De Silva 1993).

Historically, the potential of CBF for increasing food fish production among rural communities was first recognised by Mendis and Indrasena (1965) when they proposed CBF as a strategy for utilisation of the vast numbers of biologically productive small, non-perennial water bodies in Sri Lanka. CBF trials were also conducted by Fernando and Ellepola (1969) in two Sri Lankan reservoirs using Oreochromis mossambicus as stocking material. Based on these studies, Mendis (1977) recommended developing CBF in minor irrigation reservoirs of the country. A concerted attempt was made to revive this strategy in the 1980s (Chakrabarty and Samaranayake 1983; Chandrasoma and Kumarasiri 1986) but was not pursued with sufficient vigour and associated planning, and the program fell into disrepute and was abandoned. It is also relevant to note that in that era the promising strategy, pursued in most of Asia and elsewhere, perhaps very appropriately, was to develop and intensify the traditional forms of aquaculture, such as pond, cage and pen culture.

What is CBF

CBF are stock enhancement practices in water bodies that are generally incapable of supporting sustainable fisheries through self-recruiting fish populations, and where the stock is managed and owned either individually and or collectively. Accordingly, CBF practices fall within the realm of aquaculture (FAO 1994). CBF is often conducted in small water bodies, perennial and or seasonal, that retain water at least for six to eight months of the year. Often the water bodies in which CBF is practised are communally managed by village organisations that manage the water regime for other purposes, most commonly for downstream cultivation. However, in some countries (e.g. Vietnam) water bodies may be auctioned for CBF purposes by the authorities to an individual and or groups of individuals for fishery development purposes (Nguyen et al. 2001).

In CBF the natural productivity of the water body is utilised by the stocked seed, and rarely are external nutrients added to the system and or provided in the way of food for the stocked fish species. An exception may be when grass carp is stocked. In Vietnam for example, CBF yield in farmer-managed reservoirs are enhanced through feeding mainly using grass, tender cassava leaves and locally available agricultural by-products such as rice bran and cassava flour (De Silva 2003). On the other hand, encouragement of the use of small water bodies for caring for village livestock, such as cattle and water buffalo is known to improve the productivity and known to have a positive impact on fish yields (Jayasinghe and Amarasinghe 2007).

CBF have a strong social component that is pivotal to their success (Lidzba et al. 2008; Kularatne et al. 2009). In general, CBF are practised in rural areas where the great bulk of water bodies suitable for such activities are located. Hence the primary beneficiaries of CBF are rural communities that often tend to be impoverished. In CBF practices community organisations, and or their representatives that are involved in the management of the water resource, are also engaged in the management of the fishery activities.

As CBF are relatively low cost activities, with the main external input being seed stock, most developing country governments regard CBF to be relevant to and an integrated part of rural development. It is an environmentally acceptable practice with minimal external inputs (De Silva 2003), and is also a very effective and a non-consumptive secondary use of a water resource for food fish production.

Where CBF

The stock enhancement practice of CBF falls within the realm of aquaculture (FAO 1994) as the stocked seed are cared for by a management committee, an individual and or a group of individuals that will own the resource at harvest. In general, CBF are practised in small water bodies (< 40 ha), perennial and or seasonal that retain water for a minimal period of six to eight months, for easiness and facilitation of effective management, as well as optimising fish production (Chakrabarty and Samaranayake 1983; Chandrasoma and Kumarasiri 1986; Nguyen et al. 2001; De Silva et al. 2006; Wijenayake et al. 2005; Jayasinghe et al. 2006; Pushpalatha and Chandrasoma 2010). High biological productivity in these water bodies, which is generally unexploited in terms of fisheries production, is also a driving factor for utilising them for CBF development (Mendis 1977).

Small water bodies confer a number of advantages for practicing CBF. These tend to be more productive and there is minimal loss of stocked seed as they are easy to manage and keep watch. Furthermore, these often enable complete harvest at the end of the growth cycle and facilitate community involvement.

The water bodies used for CBF come under different regimes of management. In countries such as India, Lao PDR and Sri Lanka for example, these come under the jurisdiction of different authorities associated with downstream cultivation. These authorities work in conjunction with the relevant rural community who live in the vicinity of the water body, and the former are engaged in the day to day management of the water resource and, as a result, they do not fall under the common pool (open access) property regime. Accordingly, when CBF are practiced by such communities a separate entity is organised/constituted among those engaged in the water management to take care of the fishery related activities. However, almost always, the whole community would benefit from the fishery activities/CBF practices even though not directly engaged in the activity.

On the other hand, increasingly CBF are being practised in larger water bodies through a strict co-management regime, with restricted access to the fish resources (Kulatilake et al. 2010; also see Amarasinghe and Wijenayake and Chandrasoma et al., this volume). Although in these water bodies there have been fisheries based on natural recruitment, adoption of planned stocking programs together with the strict enforcement of a regime of co-management where only members of the relevant management unit are permitted to access the resource, essentially makes these a form of broadened CBF practices.

Geographically, CBF by any means are not restricted to Asia. De Silva (2003) reviewed CBF practices elsewhere, such as in Cuba and Brazil. However, in the last decade or so there has been very little information coming forth on CBF practices in other continents. It may be said that CBF will be a suitable alternative in continents where intensive aquaculture has not taken a foot hold and where the capital and technical inputs are not easily available. In the geographical regions where per capita water availability is low, such as Asia and Africa (Nguyen and De Silva 2006), CBF being a non-consumptive user of standing water, is an ideal option for fisheries enhancement.

How CBF

CBF are essentially direct stock and recapture strategies that result in significantly higher fish yields than otherwise would have been possible through natural recruitment. The fish used in CBF are typically fast growing species that feed lower in the food chain along with other determining factors including the availability of suitably sized, good quality seed stock and prevailing consumer preferences. Species that utilise the naturally produced food organisms in the water bodies are preferred, as external feed inputs are not used in CBF, apart from grass when grass carp (*Ctenopharyngodon idellus*) is stocked (De Silva et al. 2006). Use of organic fertiliser, in the form of cow dung for example, is encouraged when available, and so are other indirect approaches that increase nutrient input, such as permitting the use of the water body for livestock grazing (Jayasinghe and Amarasinghe 2007).

The species combinations in CBF and the proportion of each species used differ from region to region and country to country. These are determined through R&D (e.g. Nguyen et al. 2005; Wijenayake et al. 2005; Jayasinghe et al. 2006). The species used may be a combination of indigenous and alien species and or the latter only (Table 1). In countries such as Cambodia indigenous fish species are used mostly as the prevailing regulations discourage the use of alien species. On the other hand, in Sri Lanka where there is a relatively poor freshwater foodfish fauna, CBF is almost entirely dependent on alien species that have been used for all forms of aquaculture activities in the country for over six decades.

CBF are practices that are managed by communities living beside the water bodies. Often the primary function of water bodies used for CBF is downstream cultivation (e.g. rice), and more often than not communities are organised to manage the water resource for this purpose. For purposes of CBF, representatives from such organised bodies are drawn in. The management processes involve the planning of seed stocking (and procurement), maintaining vigilance to minimise poaching, taking care of the stock in general, conducting and selling the harvest. Figure 1 depicts schematically the CBF better management practices that are in operation in Lao PDR, and the general principle is applicable to most CBF practices, with minor regional /country variations.

As evident from Figure 1, CBF in perennial water bodies is totally dependent on the prevailing weather pattern(s) as the key stages of stocking and harvesting are dictated by the water level. Essentially, this is also the case in CBF development in non-perennial reservoirs of Sri Lanka (De Silva 1988; Amarasinghe 2006). Accordingly, the harvesting in CBF often occurs within a narrow time frame, which in a given area, can result in an oversupply of fish at that time that can also affect the farm gate price. It is imperative therefore, as CBF develops and intensifies, that adjacent CBF communities communicate with each other and arrive at appropriate harvesting and related market strategies to minimise negative impacts on farm gate price(s). On the other hand, as CBF popularise it may be that communities develop appropriate, low energy cost processing techniques as an alternative strategy.

CBF - for whom?

It has been pointed out in the previous sections the importance of community involvement in CBF. These community organisations are pivotal to the success of CBF, irrespective of the country. As CBF are mostly carried out in small water bodies, which tend to be rurally located, the primary beneficiaries are those communities that live in the vicinity of the water bodies, and who have traditionally enjoyed the use of the water resource(s) for their wellbeing. Even though the whole community (all households) may not be directly involved in CBF, the water body used is a communal property and as such all households benefit, albeit to different degrees depending on the extent of involvement in the CBF practice per se. For example, those households that contribute to keeping watch of the stock, transportation of seed stock and or taking an active role in the management committee will be entitled to a higher share of the benefits.

In Lao PDR communities that practice CBF have evolved three types (Table 2) of benefit sharing schemes that are interrelated with the harvesting protocols employed by each (Saphakdy 2009; Phomsouvanh et al. 2015). It is evident from Table 2 that every household of the village community benefits and, importantly, a certain proportion of the CBF returns are almost always utilised for improving social amenities in the community. Admittedly, such well organised and structured benefit sharing protocols do not operate in every country. With the broadening of CBF into large perennial water bodies, such as in Sri Lanka, the common community gains are administered by the "fisher societies" through a consensual approach.

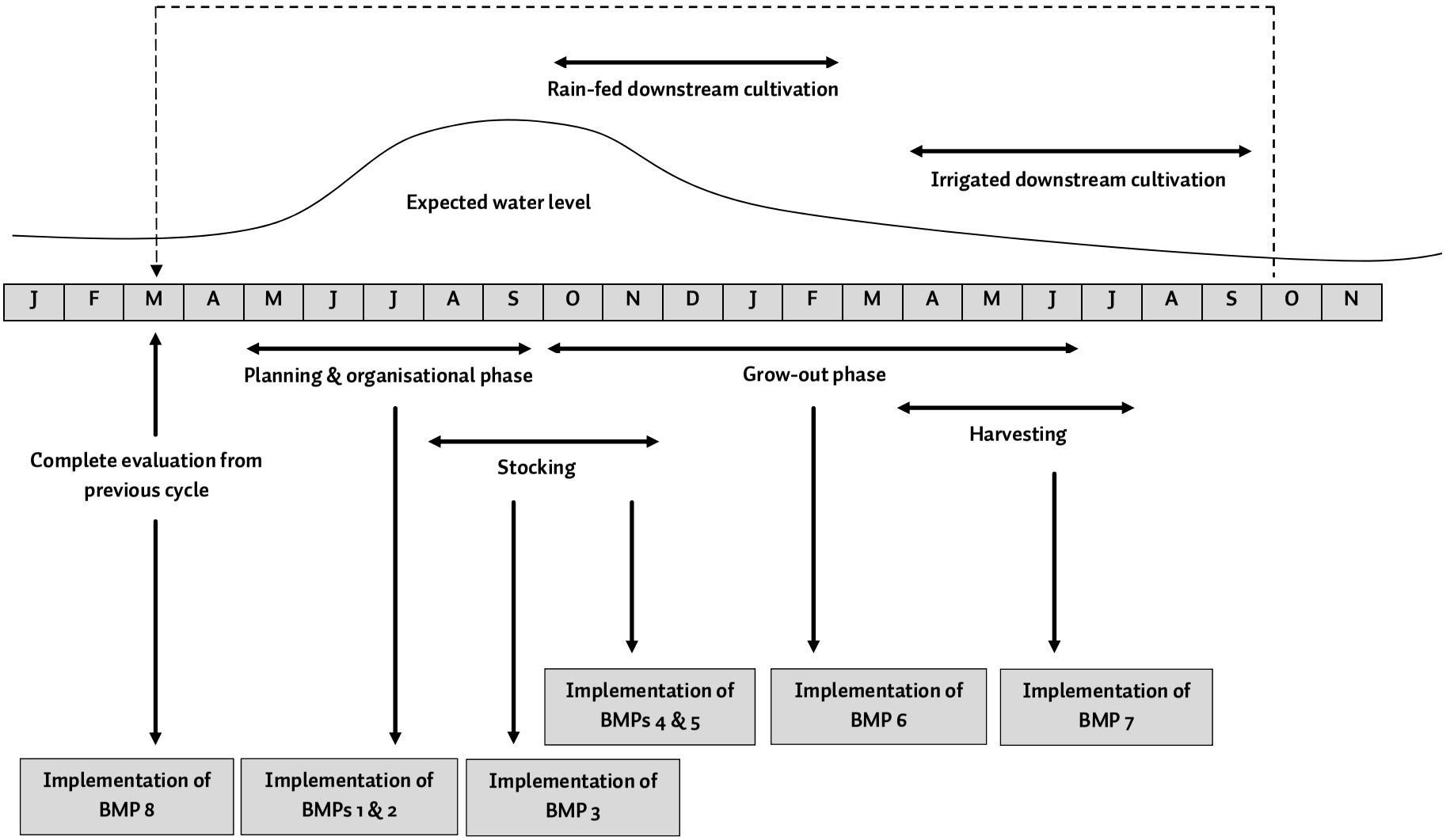
Table 1. Commonly used species in CBF practices in four different countries (compiled from varying sources; * alien to the country).

Cambodia	Lao PDR	Sri Lanka	Vietnam
Pangasianodon hypophthalmus	*Catla catla**	*Catla catla**	*Cirrhinus mrigal**
Channa striata	*Aristychthys nobilis**	*A. nobilis**	*A. nobilis**
Clarias batrachus	*Hypophthalmichthys molitrix**	*H. molitrix**	*H.molitrix**
C. macrocephalus	*Oreochromis niloticus**	*O.niloticus**	*Ctenopharyngodon idellus**
Anabas testudineus	*Cyprinus carpio*		*Cyprinus carpio*
Barbonymus gonionotus	*B. gonionotus*		
	Labeo chrysophekadion		
	Cirrhinus molitorella		

Table 2. The three basic forms of management (based on the harvesting patterns) of the water bodies that are adopted through a consensus of each of the communities in Lao PDR. Modified after Phomsouvanh et al. (2015).

Harvesting	Gains to community households	Distribution of monetary gains
Category 1		
Permit the village households to fish for their daily needs using scoop nets and hook and line, five months after stocking. The community embarks on harvesting the remaining stock via a ticket system where the public can purchase the right to catch fish for sale, when the water level recedes approximately 8 to 9 months after stocking. The ticket price varies according to the gear to be used (for example, use of a lift net, often operated by women folk, 20, 000 Kip; cast net, 40, 000 Kip; where 8,000 Kip= 1 US $). The harvesting associated with ticket sales could go on for two to three days, but generally there is about 10% reduction in the ticket price after the first day.	Daily fish needs in this manner and households are not permitted to catch for sale; gear limited to small drag net and traditional traps only.	Restricted to ticket sales; 10-20 % of the proceeds reserved for purchase of seed stock for the next CBF cycle. The rest of the monetary gains invested in community amenities. These include improvements/developments such as improvement to the local school (providing electricity), improving the temple community hall, investing on improving another water body in the village for CBF activity by improving the dam structure/sluice gates etc.
Category 2		
Similar approach to Category 1.	Daily fish needs and households are not permitted to catch for sale; gear limited to small drag net and traditional traps only; a portion of the ticket sales are provided to each household.	Of the ticket sales 10- 20 % is retained for the purchase of seed stock for the next cycle. 50 % of the remainder is divided among the households; every household in the community is entitled for this benefit. The rest is utilised as follows: 6% advisors and committee members; 6% accountant and cashier; 10% labour (keeping watch etc.); 20% improving public amenities; 38% other social welfare, religious activities and associated hospitality.
Category 3		
Harvested only as the water level recedes, generally 8-9 months post stocking with engagement of the whole community; harvesting is publicised widely and the harvest auctioned on site.	Fish for communal social occasions/ festivities; monetary gains based on net gains after harvest.	50% of the total revenue is shared amongst households of the community. The remainder is disbursed as follows: 20% purchase of fry and fingerlings; 6% advisors and committee members; 6% accountant and cashier; 10% labour (keeping watch etc.); 20% improving public amenities; 38% other social welfare, religious activities and associated hospitality.

Figure 1. A schematic representation of elements of better management practices for CBF in Lao PDR. (Descriptions of BMPs 1-8 are provided in De Silva 2012$_a$).



Conclusions

CBF have come a long way since the initial recognition of its potential with regard to utilising small, non-perennial water bodies (Mendis 1977). These practices have become the backbone of inland food fish supplies in some countries, such as Sri Lanka. Based on the utilisation of small water bodies in Asia, that is reputed to cover nearly 67 million ha, De Silva (2003) previously predicted that using only 50% of this acreage for CBF could increase food fish supplies by 2 million t/yr. Since this prediction was made, many related developments that would further facilitate the returns from CBF have occurred. Primarily, CBF management methods have improved considerably and, in China for example, the mean yield from CBF has reached 1,746 kg/ha/yr (Wang et al. 2014). As such, it will be pertinent to revisit old projections and adjust the needs and recognise the constraints that will enable more realistic and higher food fish targets to be achieved through CBF. Most importantly, this increased food fish production will be forthcoming from essentially environmentally friendly practices that could be sustained in the long term.

Another important development facilitating adoption of CBF is the recognition by governments of many developing nations in Asia that CBF is a low cost strategy that will enhance food fish production and augment rural incomes. Consequently, governments have, where appropriate, amended and or enacted regulations that facilitate CBF developments (e.g. *Agrarian Services Act* 47 of 2000 of Sri Lanka; Government of Cambodia 2010, The Strategic Planning Framework for Fisheries 2010–2019). Changes to governmental policies and Acts affecting CBF will be crucial to their further development in the next decade, particularly in harnessing the large extent of suitable water bodies for CBF.

CBF may also be an appropriate strategy to be tested and adopted in regions where concerted attempts at popularising intensive aquaculture have not yielded the desired outcomes. Equally, it could be a suitable strategy to be implemented where there is a dearth of suitably trained human capital for practicing intensive aquaculture. It should, however, be noted that CBF success will be optimised only if the practices are geared to existing micro-climatic and geographic conditions; this will entail conducting appropriately planned preliminary trials to ascertain the most suitable species, the species combinations, harvesting regimes and strategies, among other needs.

It is also important to point out that future CBF activities will have to take into account potential climate change impacts. Practice and success of CBF are dependent on the prevailing weather patterns and relevant adjustments to climate change impacts will be critical to maintaining optimal returns.

References

Amarasinghe, U.S., 2006. Culture-based fisheries development in Sri Lanka: a case study. In: De Silva, S.S., Amarasinghe, U.S., Nguyen, T.T.T. (Eds.), *Better-practice approaches to culture-based fisheries development in Asia*. pp. 50-72. ACIAR Monograph 120.

Cao, L., Naylor, R., Henriksson, P., Leadbitter, D., Metian, M., Troell, M. and Zhang, W., 2015. China's aquaculture and world's wild fisheries. Curbing demand for wild fish in aquafeeds is critical. *Science*, 347, issue 6238; 133-135.

Chakrabarty, R.D. and Samaranayake, R.A.D.B., 1983. Fish culture in seasonal tanks in Sri Lanka. *Journal of Inland Fisheries*, Sri Lanka, 2; 125-140.

Clay, J., 2011. Freeze the footprint of food. *Nature*, 475; July 21, 2011.

Chandrasoma, J. and Kumarasiri, W.S.A.A.L., 1986. Observations on polyculture of fish in seasonal tanks in Sri Lanka. *Journal of Inland Fisheries*, Sri Lanka, 3; 49-55.

De Silva, S.S., 1988. Reservoirs of Sri Lanka and their fisheries. *FAO Fisheries Technical Paper*, 298; 128 pp.

De Silva, S.S., 2003. Culture-based fisheries: an underutilized opportunity in aquaculture. *Aquaculture*, 221; 221-243.

De Silva, S.S., 2012. Aquaculture - a newly emergent food production sector- and perspectives of its impacts on biodiversity and conservation. *Biodiversity and Conservation*, 21 (12); 3187-3220.

De Silva, S.S., 2012_a. *Better Management Practices for Culture-Based Fisheries, Lao PDR*. 46 pp.; http://enaca.org/publications/inland-aquaculture/better-management-practices-culture-based-fisheries-lao.pdf.

De Silva, S. S. and Soto, D., 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. *FAO Fisheries Technical Paper*, 530; 137-215.

De Silva, S.S., Amarasinghe, U.S. and Nguyen, T.T.T. (Eds), 2006. *Better-practice approaches to culture-based fisheries development in Asia*. ACIAR Monograph 120, 96 pages (translated into Laotian, Sinhalese, Tamil and Vietnamese).

FAO (Food and Agriculture Organization of the United Nations), 1994. Aquaculture production 1986-1992. *FAO Fisheries Circular*, Vol. 815, Revision 6. Rome, Italy, 214 pp.

FAO, 1999. Irrigation in Asia in figures. FAO, Rome, Italy.
FAO 2009. *How to feed the world in 2050*. FAO, Rome, 36 pp.

FAO, 2011. World aquaculture 2010. *FAO Fisheries and Aquaculture Technical Paper* 500/1 Rome, Italy, 120 pp.

Fernando, C.H. and Ellepola, W.B., 1969. A preliminary study of two village tanks (reservoirs) in the Polonnaruwa area with biological notes on these reservoirs in Ceylon. *Bulletin of Fisheries Research Station*, Ceylon, 20; 3-13.

Froese,R., Zellert, D., Kleisner, K. and Pauly, D., 2012. What catch data can tell us about the status of global fisheries? *Marine Biology*, 159; 1283-1292.

Godfray, H.C.J., Beddington, J.R., Crute, I. R., Haddard, L., Lawrence, D., et al., 2011. Food security: the challenge of feeding 9 billion people. *Science*, 327 (February 2011); 812-818.

Hanjra, M.A. and Qureshi, M.E., 2010. Global water crisis and future food security in an era of climate change. *Food Policy*, 35; 365-377.

Indrasena, H.H.A., 1965. Freshwater fishery resources. *Bulletin of Fisheries Research Station*, Ceylon, 18; 1-4.

Jayasinghe, A. and Amarasinghe, U., 2007. Buffaloes in favour of culture based fisheries in Sri Lanka. *Aquaculture Asia Magazine*, 12 (3); 2-8.

Jayasinghe, U.A.D., Amarasinghe, U.S. and De Silva, S.S., 2006. Culture-based fisheries in non-perennial reservoirs of Sri Lanka; Influence of reservoir morphometry and stocking density on yield. *Fisheries Management and Ecology*, 13; 157-164.

Klinger, D. and Naylor, R., 2012. Searching for solutions in aquaculture: charting sustainable course. *Annual review of Environment and Resources*, 37; 247-276.

Kularatne, M.G., Amarasinghe, U.S., Wattage, P. and De Silva, S.S., 2009. Evaluation of community participation for the development of culture-based fisheries in village reservoirs of Sri Lanka. *Aquaculture Economics & Management*, 13; 22–38.

Kulatilake, M., Liyanage, H.S.W.A., Fernando, W.M.J.R., Chandrasoma, J. and der Knapp, M.V., 2010. Development of co-management in inland fisheries in Sri Lanka: case studies of Senanayake Samudra and Mahavilachchiya reservoirs. *Aquatic Ecosystem Health & Management*, 13; 281-287.

Leung, T.L.F. and Bates, A.E., 2013. More rapid and severe disease outbreaks for aquaculture in the tropics: implications for food security. *Journal of Applied Ecology*, 50; 215-222.

Lidzba, C, Siriwardena, N. and Kumara U., 2008. Fish farming in seasonal reservoirs: Beyond technical feasibility. In: M.J.S. Wijeyaratne and U.S. Amarasinghe (Eds.) *Participatory Approaches to Reservoir Fisheries Management: Issues, Challenges and Policies*. pp. 151-262. Sri Lanka Association for Fisheries and Aquatic Resources, Colombo, Sri Lanka.

Mendis, A.S., 1965. A preliminary survey of 21 Ceylon lakes: 2. Limnology and fish production potential. *Bulletin of Fisheries Research Station*, Ceylon, 16; 7-16.

Mendis, A.S., 1977. The role of man-made lakes in the development of fisheries in Sri Lanka. *Proceedings of the Asia-Pacific Fisheries Council*, 17; 247-254.

Nguyen, T.T.T. and De Silva, S.S., 2006. Freshwater finfish biodiversity and conservation: an Asian perspective. *Biodiversity and Conservation*, 15; 3543-3568.

Nguyen, Son H., Bui, Anh T., Le, L.T., Nguyen, Thuy T.T. and De Silva, S.S., 2001. Aspects of the culture-based fisheries in small, farmer-managed reservoirs, based on three production cycles, in two provinces of northern *Vietnam. Aquaculture Research*, 32; 975- 990.

Nguyen, H. S., Bui, A. T., Nguyen, D. Q., Truong, D. Q., Le, L. T., Abery, N.W. and De Silva, S.S., 2005. Culture-based fisheries in small reservoirs in northern Vietnam: effect of stocking density and species combinations. *Aquaculture Research*, 36; 1037-1048.

Nguyen Lam Anh, Vinh Dang Hoa, Bosma Roel, Verreth Johan, Leemans Rik and De Silva Sena S., 2014. Simulated impacts of climate change on current farming locations of striped catfish (*Pangasianodon hypophthalmus*; Sauvage) in the Mekong Delta, Vietnam. *Ambio*, 43; 1059-1068.

Phomsouvanh Akhane, Saphakdy Bounthong and De Silva Sena S., 2015. Production trends, monetary returns and benefit sharing protocols from the extensive aquaculture practice of culture-based fisheries in rural communities in Lao PDR. *Aquaculture*, 439; 29-38.

Pushpalatha, K.B.C. and Chandrasoma, J., 2010. Culture-based fisheries in minor perennial reservoirs in Sri Lanka: variability in production, stocked species and yield implication. *Journal of Applied Ichthyology*, 26; 98-103.

Saphakdy, B., Phomsouvanh, A. Davy, B., Nguyen, T.T.T. and De Silva, S.S., 2009. Contrasting community management and revenue sharing practices of culture-based fisheries in Lao PDR. *Aquaculture Asia Magazine*, 14 (3); 2-6.

Subasinghe, S., Soto, D. and Jia, J., 2009. Global aquaculture and its role in sustainable development. *Reviews in Aquaculture*, 1; 2-9.

Tacon, A.G.J, Metian, M., Turchinni, G. and De Silva, S.S., 2010. Responsible aquaculture and trophic level implications to global fish supply. *Reviews in Fisheries Science*, 18; 94-105.

Wang, Q, Cheng L., Liu, J., Li, Z., Xie, S. and De Silva, S.S., 2014. Freshwater Aquaculture in PR China: Trends and Prospects. *Reviews in Aquaculture*, 20 pp.

Wijenayake, W.M.H.K., Jayasinghe, U.A.D., Amarasinghe, U.S., Athula, J.A., Pushpalatha, K.B.C. and De Silva, S.S., 2005. Culture-based fisheries in non-perennial reservoirs in Sri Lanka: production and relative performance of stocked species. *Fisheries Management and Ecology*, 12; 249-258.

World Fish Centre, 2011. Aquaculture, fisheries, poverty and food security. *WFC Working Paper* 2011/65, Penang, Malaysia, 62 pp.