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Culture based fisheries in Asia are a strategy to augment food security

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Abstract Fish account for nearly 30 % of the animal protein intake in developing countries. Until very recently the great bulk of food fish supplies were of hunted origin, although farmed supplies have been growing at a steady rate of about 6 % per year over the last two decades. It is estimated that nearly 40 million t of food fish will be required to meet the increasing demand by the year 2050. The shortfall in supplies are unlikely to be met through intensive aquaculture alone as the drain on primary resources, physical and biological, will be excessive and environmental integrity will also be at stake. On the other hand, it is estimated that there are nearly 67 million ha of small water bodies in Asia alone, that are primarily irrigational. Small water bodies are ideal for culture based fisheries (CBF) development, a form of extensive aquaculture practice based on the principle of stock and recapture, and often managed communally. Significantly higher production levels have been obtained in developing countries that have adopted CBF, such as, for example, China. If 20 % of the available area of small water bodies were mobilised for CBF in the next decade, with the aim of achieving 50 % of the mean yield attained in CBF practices in China (1746 kg/ha/yr), the food fish production in Asia alone would be increased by approximately 10.72 million t /yr. The pros and cons of adopting CBF practices to augment the global food fish supplies are discussed and the advantages of CBF over intensive aquaculture in the context of use of natural resources and maintaining environmental integrity are also dealt with. Furthermore, small water bodies suited for CBF development are often located in rural areas of developing countries where the local populations, which often tend to be impoverished compared to their urban counterparts, stand to benefit most.

Keywords Culture-based fisheries · Food fish supplies · Aquaculture · Natural resources · Community management

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Introduction

Throughout our evolutionary history fish have been an important constituent of the human diet, and is even thought to have contributed to the development of the human brain, thereby making us what we are (Crawford et al. 1999; Cunnnane and Stewart 2010). Fish currently account for nearly 30 % of animal protein intake, being significantly higher among rural communities in developing countries (FAO 2011a). Fish also often provide an affordable source of animal protein for poor, remote communities. The nutritional and related health benefits arising from fish consumption, compared to types of red meat, in particular polyunsaturated fatty acids in the former, are becoming increasingly evident (e.g. Sastry 1985; Simopoulos 1991; Horrocks and Yeo 1999; Calder 2004; Young and Conquer 2005; Seki et al. 2009; Dawczynski et al. 2010; Siriwardhana et al. 2012; Kim et al. 2013). Since 1950 the per capita fish consumption has increased from 6 to 19.2 kg/cap/yr in 2012 (Committee on World Food Security 2014). However, some important regional and national differences exist: Asia for example accounts for two thirds of global fish consumption, averaging 21.4 kg/cap/yr in 2011, a level similar to Europe (22.0 kg/cap/yr) and North America (21.7 kg/cap/ yr). The above report drew attention to the fact that, thus far, limited attention has been given to fish as a key element in food security and nutrition at a national level and in wider development discussions and interventions. In the recent past the numbers of narratives on the importance of fish in food security in general have increased (Kawarazuka and Běně 2010; Belton and Thilsted 2014; Youn et al. 2014; Běně et al. 2015, 2016). However, none of these narratives have attempted to address ways and means of increasing the future needs of fish food supplies.

It is estimated that even at the current rate of fish consumption the world will require an additional 30–40 million t by 2050 to account for the expected population increase. The global food fish supplies, until recently, were predominantly of a hunted origin — based on wild capture fisheries- and only in the last decade has its predominance come to be based on a farmed supply, like all our other staples (De Silva 2012). The situation is further exacerbated as the traditional fish supplies from the marine capture fisheries, at best, have plateaued at around 100 million t, of which only 75 % is available for direct human consumption, as many of the traditionally fished stocks have reached a dire state (Froese et al. 2012). On the other hand, since the 1970s there has been a significant upsurge in global aquaculture production, averaging a growth rate of around 6 % per year in the last three decades (FAO 2011a), the highest for any primary production sector. The growth of the aquaculture sector has contributed significantly to narrowing the gap between supply and demand for food fish, and has led towards the predominance of farmed supplies in global food fish consumption (Subasinghe et al. 2009, 2012; FAO 2011a).

Aquaculture production reached 76,321,310 t in 2011 (FAO 2014), with the Asia-Pacific region contributing over 80 %, and PR China being the leading nation accounting for 65.7 % of the total global production (Wang et al. 2015). The growth surge in aquaculture has been subjected to a higher degree of "policing" by the public, particularly in the wake of establishment of the Convention on Biological Diversity and the generally accepted notion that all major developments should be sustainable (De Silva and Davy 2010). Production of food fish from aquaculture, until now, is primarily through intensive mono- and poly- culture practices, conducted in ponds, cages, pens, recirculation systems, as well as rope and raft culture of molluscs, and other wide ranging practices. Intensification of aquaculture practices has led to the use of artificial feeds, prophylactics for disease prevention, drugs of varying sorts for disease control, growth promoters and other ways and means of increasing yields (e.g. see Rico et al. 2012), essentially reflecting comparable developments in land based agriculture and animal husbandry of the past.

Over the years particular aquaculture developments, such as the shrimp culture boom in Asia and south America, have been subjected to heavy criticisms for clearing mangroves, land grabbing and high levels of effluent discharge impacting on water ways (Primavera 1997; Páez-osuna et al. 1998; Páez-osuna 2001; Thornton et al. 2003; Primavera 2005; Marhaba et al. 2006; Guimar es et al. 2010). It is thought some of the environmentally destructive practices associated with aquaculture, especially in respect of mangrove clearing for shrimp farming, however, is a thing of the past (Stevenson et al. 1999; Yadava 2002; De Silva 2012). Nevertheless, environmental impacts resulting from intensive aquaculture practices are a major concern and remedial measures and alternative culture practices are being sought (e.g. Cai et al. 2012; Lin et al. 2015; Wang et al. 2016).

Intensification leads to environmental degradation, increased demand on resources—physical and biological, and also raises ethical issues on the very high proportion of use of certain biological resources such as fish meal and fish oil in aquaculture (Tacon et al. 2010). More often than not when challenges of feeding nine billion people are considered the issues raised are competition for land, water and energy and the over exploitation of fishery resources (Hanjra and Qureshi 2010; Godfray et al. 2011). The general consensus is that these issues are further exacerbated by impending climate change impacts even particularly on aquaculture (De Silva and Soto 2009; Leung and Bates 2013; Nguyen et al. 2014). One therefore 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 thereby ensuring food security (e.g. Lin et al. 2015).

Providing food security to a growing population remains a major concern of the global community, with an estimated 797 million people being undernourished at present (FAO, IFAD and WFP 2015). In the wake of the above concerns, this paper attempts to discuss the importance of culture based fisheries (CBF), a form of extensive aquaculture, as a plausible strategy for augmenting food fish security in developing countries in particular, but not as an alternative to intensive aquaculture. An attempt is made here to demonstrate that CBF will contribute to food security through increasing availability, one of the four facets of the latter. To this end examples are drawn from developing countries in Asia that have successfully adopted CBF, which has resulted in significant increases in food fish production, particularly benefitting rural communities.

What is culture based fisheries (CBF)?

The FAO (2011b) defined CBF as activities aimed at supplementing or sustaining the recruitment of one or more aquatic species and raising the total production or the production of selected elements of a fishery beyond a level, which is sustainable through natural processes. Therefore, CBF will consist of two phases—a farmed phase for the provision of stocking material, and a wild phase, which will, however, be cared for to a certain degree. CBF related stock enhancement practices and the associated care for the stocked seed until harvest is often carried out by communities living in the vicinity of water bodies. This is achieved by a co-management process, which provides ownership to the respective communities. Such practices are considered to fall within the realm of aquaculture (De Silva 2003) and differ greatly from the wide array of other enhancement practices (Lorenzen and Garaway 1998; Welcomme and Bartley 1998; De Silva and Funge-Smith 2005; Weimin et al. 2010).

CBF in different forms are practised widely, but are most predominant in Asia. In general, CBF are conducted in small water bodies, natural and quasi natural, perennial and/or seasonal that retain water for a minimum of 8 months in the year. Such water bodies are often located in remote villages and are irrigational, primarily for downstream rice cultivation. In most countries the water resource is managed through a system of community organisations facilitated through relevant regulatory procedures that may differ from country to country. FAO (1999) estimated that there are nearly 66.7 million ha of small water bodies in Asia alone, and De Silva (2003) suggested that mobilisation of even a small proportion of these for CBF developments will significantly increase food fish production. CBF developments in water bodies, which are predominantly located in rural areas, will benefit communities living in these areas, who are generally poorer than their urban counterparts (Yunus 2007). Developments in inland fisheries in developing countries may contribute significantly to global supplies of food fish in the future (Beard et al. 2011; Youn et al. 2014) and CBF may play a major role.

CBF is essentially an extensive form of aquaculture where suitable seed are stocked enabling them to feed on the naturally occurring organisms in the water body, and attain a marketable size in 6–8 months. The choice of stocked species is based on their feeding niches and local preferences, ensuring that all naturally produced food organisms are utilised, mirror imaging pond polyculture systems (Pillay 1990; Milstein 1992). The principles of CBF practices have been summarised by De Silva et al. (2006), and those specific to individual countries and or a particular aspect, including community engagement, are adequately documented (see for example Lorenzen et al. 1998; Middendorp and Balarin 1999; Nguyen et al. 2001; Jayasinghe et al. 2005; Nguyen et al. 2005; Wijenayake et al. 2005; Valbo-Jørgensen and Thompon 2007; Kularatne et al. 2009; Saphakdy et al. 2009; Pushpalatha and Chandrasoma 2010; Phomsouvanh et al. 2015). Overall, the key features that reflect best practice of CBF can be summarised as:

- CBF is a secondary user of existing water resources and is non-consumptive of this valuable resource. It is mostly practised in those water bodies that are incapable of supporting and sustaining any form of fishery through natural recruitment
- CBF is a stock enhancement practice where the ownership of the stock is defined and therefore falls within the realms of aquaculture, an extensive aquaculture practice
- The species used will differ from practice to practice but in general will conform to ensure that all food niches are utilised by the species used, as far as possible, as in intensive polyculture practices
- CBF is often a communal activity where existing village organisations constituted for water resource management, primarily for downstream agricultural activities, are utilised through a co-management system, and/or through a mechanism of leasing of suitable water bodies from the authorities (e.g. Vietnam; Nguyen et al. 2001, 2005)
- The sharing of benefits, food fish and monetary gains from the sale of fish may differ among communities, even within a country/region, and
- Because CBF practices call for continued vigilance of the stock and planning related to harvesting, it generates a high degree of synergy in the community, which brings about better harmony and common societal gains.

Trends in CBF

Early phase

Perhaps equivalents of and/or crude variations of CBF may have been in operation, on a small and a less organised scale, many decades ago, contributing little to food fish production. The strategy of using the multitude of small, preferably non-perennial reservoirs that retain water for a minimum period of 8 months to enhance food fish production through a stock and recapture strategy was proposed by Mendis (1977). However, in that period of fisheries development the major emphasis was on intensive aquaculture, and the great bulk of resources, including seed stock, were used for this purpose. Also during this era the artificial propagation techniques for most of the cultured species were at a development and consolidation stage and were a limiting resource even for intensive aquaculture developments in most countries. In addition to the latter, there were other reasons for the failure of CBF, among which were lack of adequate planning and mobilisation of village communities, who were primarily agriculturists, for a fisheries activity (Middendorp and Balarin 1999; Kularatne et al. 2009).

Intensive aquaculture continued to grow over the last three decades with a resulting increase in its contribution to global food fish production (Fig. 1). In countries where lacustrine water resources are available or had been created for other purposes, CBF began to be initiated. This occurred in a many countries, among which, for example, were Bangladesh (Middendorp and Balarin 1999; Valbo-Jørgensen and

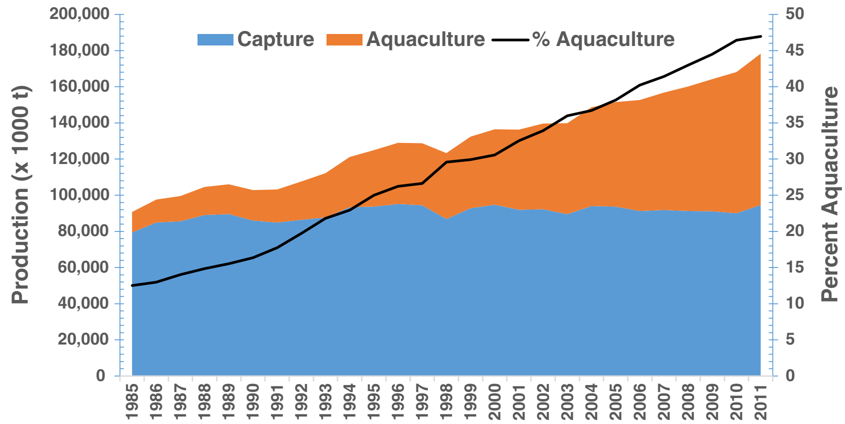

Fig. 1 The trends in food fish production from capture fisheries and aquaculture, and the percent contribution of the latter to the total (based on data from: http://www.fao.org/fishery/topic/166235/en)

Thompon 2007), Cuba (Quiros 1998), China (Lu 1992; Wang et al. 2015) and Sri Lanka (Chakrabartly and Samaranayake 1982; Thayaparan 1982; Chandrasoma 1986; Chandrasoma and Kumarasiri 1986). These past developments were reviewed and their potential to significantly impact on food fish production highlighted by De Silva (2003).

Recent developments and associated advances in CBF

Major developmental strides in CBF have occurred in the last decade when research and development work on CBF was brought to the forefront, particularly in some Asian nations. It is unfortunate that CBF production statistics are often not maintained as a separate entity, apart from in China, and hence the overall direct impact of it on food fish supplies, at least currently, is difficult to quantify. However, this omission is partially mitigated by case studies drawn from several countries.

As in all forms of aquaculture, China dominates CBF in the world. Most importantly, the overall production has steadily increased over the last decade (Fig. 2), with the average yield per ha nearing 1800 kg (Wang et al. 2015). A unit area production of around 1800 kg/ha/yr for an extensive aquaculture system where the only major input is seed is remarkable. Considering that China is reputed to have a reservoir area of 2,3002,000 ha (Weimin 2009), and the consistent increase in production per unit area over the last decade one could expect the food fish production from CBF in reservoirs in China to reach 5 million t by the end of the current decade. On the other hand, the very high level of production in China resulted from the polyculture of major Chinese carp species and use of high levels of fertilisation to promote growth of plankton. These practices resulted in eutrophication and environmental problems in associated watersheds, and have led to major changes in culture practices—primarily a shift to high value species and reduction in the use of fertiliser (Lin et al. 2015; Wang et al. 2016).

Lao PDR, a land-locked nation in South East Asia (14–18° 00′ N; 100–108° 00′ E) with a population of 6.6 million and per capita GDP of US$3,100 per annum, is considered one of the most impoverished nations in Asia (https://www.cia.gov/library/publications/the-world-factbook/geos/la.html). The main animal protein source for the population is freshwater fish, nearly 70 % of which is from aquaculture (FAO 2014). In view of the impending limitations on continued intensification (e.g. feeds, capital outlay, human capacity etc.) of aquaculture, the Government of Laos embarked on a major program to develop CBF in small water bodies in rural areas to augment food fish supplies and nutrition (Ministry of Agriculture and Forestry 2010).

CBF practices in Laos are conducted under one of three management regimes (Saphakdy et al. 2009; Phomsouvanh et al. 2015) based on the nature of benefit sharing, and decided upon by the individual communities. Irrespective of the management regime in operation the production from CBF is significant, and each of the communities gain in the form of food fish and supplementary income from sales, contributing to food security. For example, the overall mean gross production levels (kg/cycle) ranged between 1350–2844, 650–4622, and 2750–8759 for management regimes 1, 2 and 3 water bodies, respectively. Similarly the revenue (in Kip; 8000 Kip = 1 US$) per cycle ranged between 108,000–61,500,000, 1,700,000–78,150,000, and 697,000–171,750,000, respectively. Figure 3 provides a snap shot of the mean and related parameters on production for each of the management categories/regimes which, and clearly indicates that with practice the production increased to an optimal level and overall the yields from CBF are a boon to food fish availability and supplementary income to village communities. Laos is bestowed with a renewable water resource estimated at 333.5 km^3 (https://www.cia.gov/library/publications/the-world-factbook/geos/la.html), the great bulk of which is located in rural areas and is primarily used for irrigating downstream agriculture but is

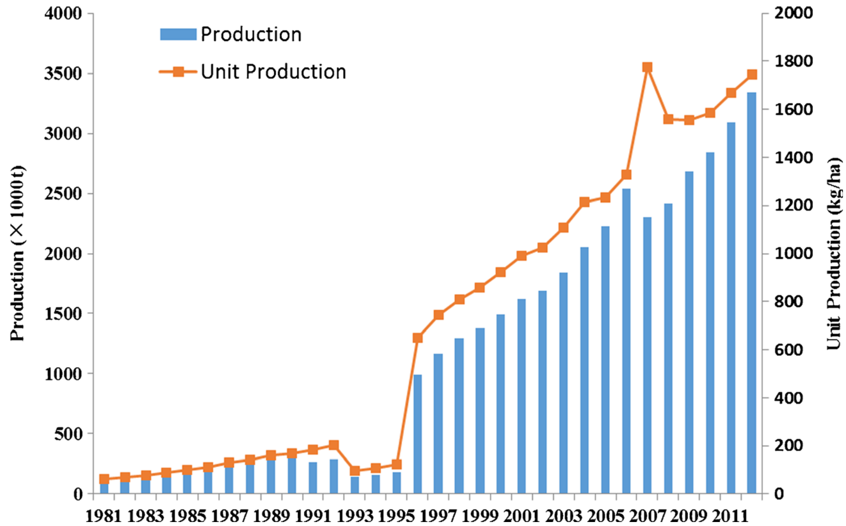

Fig. 2 The trends in CBF production, the total and per unit area/ year in inland waters in PR China (from Wang et al. 2015)

equally suitable for CBF practices. In the ensuing decades CBF will become a significant contributor of food fish availability to rural Laotian communities, the main source of animal protein of the poor.

Sri Lanka offers a good example of the application of R & D efforts on CBF, over the last decade or more, and strides that have been made in respect of consolidating CBF developments (Jayasinghe et al. 2005; Wijenayake et al. 2005). The major results of application of R and D efforts on CBF over the years that have contributed to an increase in food fish supplies, particularly among rural populations are summarised as follows (modified after Amarasinghe and Wijenayake 2015):

- A science based objective method for selecting non-perennial and perennial water bodies for CBF practices (De Silva et al. 2004), thereby avoiding waste of resources, in particular seed, 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 systematically on a large scale in village reservoirs in the 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 (Fig. 4), the major contribution purported to be from CBF.

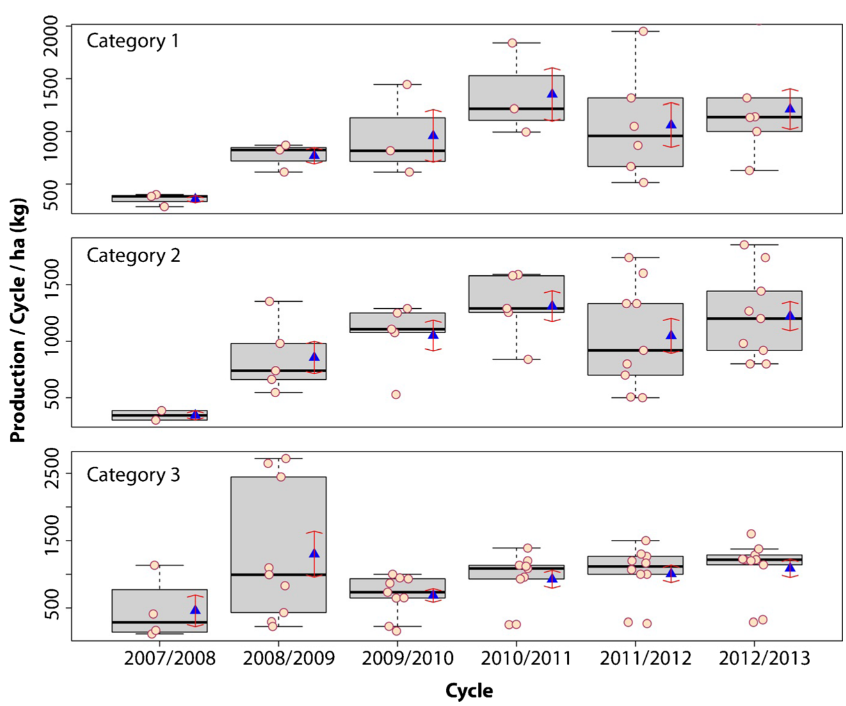

Fig. 3 Boxplots presenting the distribution of production per cycle per ha (kg) in the three categories of CBF practices, for the period from 2007 to 2013. Bold horizontal bars are the medians, circles represent data points for each water body and triangles represent the means with ±SE among water bodies (adopted from Phomsouvanh et al. 2015)

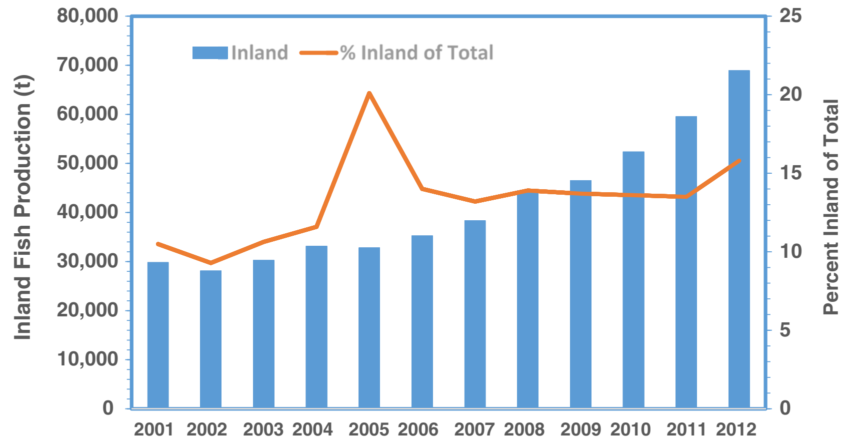

Fig. 4 Trends in inland food fish production in Sri Lanka and its percent contribution to the total. Based on data from: http://www.naqda.gov.lk/fish_production.php

- 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 (Table 1). During this period the cumulative extent of non-perennial reservoirs utilized for CBF development increased from 2677 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 organization sparked off an ancillary sector of fry to fingerling rearing, bringing about employment opportunities and economic gains to rural households, and virtually eliminating the bottle neck on fingerling supplies.
- In recent times, CBF have 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 (Chandrasoma et al. 2015; Fig. 5).
- Increased fish yields through CBF activities also have expanded the associated value and market chains benefiting rural communities through added employment opportunities.

Table 1 The numbers of seed stocked in millions (fin fish and giant freshwater prawn- GFWP) in CBF practices in Sri Lanka over the years. Based on data extracted from http://www.naqda.gov.lk/fish_production.php

Year	Finfish fingerlings	GFWP post larvae
2006	12.75	0.36
2007	12.18	0.44
2008	17.48	4.11
2009	27.07	8.06
2010	34.34	11.51
2011	44.72	11.36
2012	36.98	14.53
2013	48.79	20.43

It is evident from Fig. 5 that adoption of CBF practices in both minor- and medium- sized reservoirs have resulted in significant increases in food fish production. Admittedly, fish production in Sri Lankan reservoirs has not reached the levels of that in China (Fig. 2), but points to the possibilities of increasing production through improvements to existing CBF practices, including community management. The adoption of CBF practices in medium and large sized reservoirs in Sri Lanka, through a strictly enforced co-management strategy, can be considered a major step towards increasing food fish production (Pushpalatha and Chandrasoma 2010; Chandrasoma et al. 2015).

CBF also have been adopted in small reservoirs and beels (a term for billabong or a lake-like wetland with static water) and/or equivalents in Bangladesh (Middendorp and Balarin 1999; Valbo-Jørgensen and Thompon 2007) and in Vietnam (Nguyen et al. 2001, 2005) for example, and its potential to improve food fish supplies in Indonesia is acknowledged (Kartamihardja 2015). Conflicts of interests between leaseholders of water bodies and fish farmers and associated issues in CBF developments in Bangladesh have been highlighted and remedial measures suggested (Valbo-Jørgensen and Thompon 2007). In all cases however, it is known that the adoption of CBF has enabled communities to obtain fish yields far above the levels that would have been attained in the pre-CBF era.

The other noticeable trend in CBF practices is to stock giant freshwater prawn (*Macrobrachium rosenbergii*) in view of its high market value and in spite of the relatively low recapture rates (Jutagate and Rattanachai 2010; Sripatrprasite and Lin 2003; Jindapun and Sungkapaitoon 2006; Chandrasoma et al. 2015). Use of giant freshwater prawn in many other forms of extensive aquaculture practices such as, for example, rice-fish culture, is becoming popular, a trend driven by the high market value of this commodity (Ahmed and Garnett 2010).

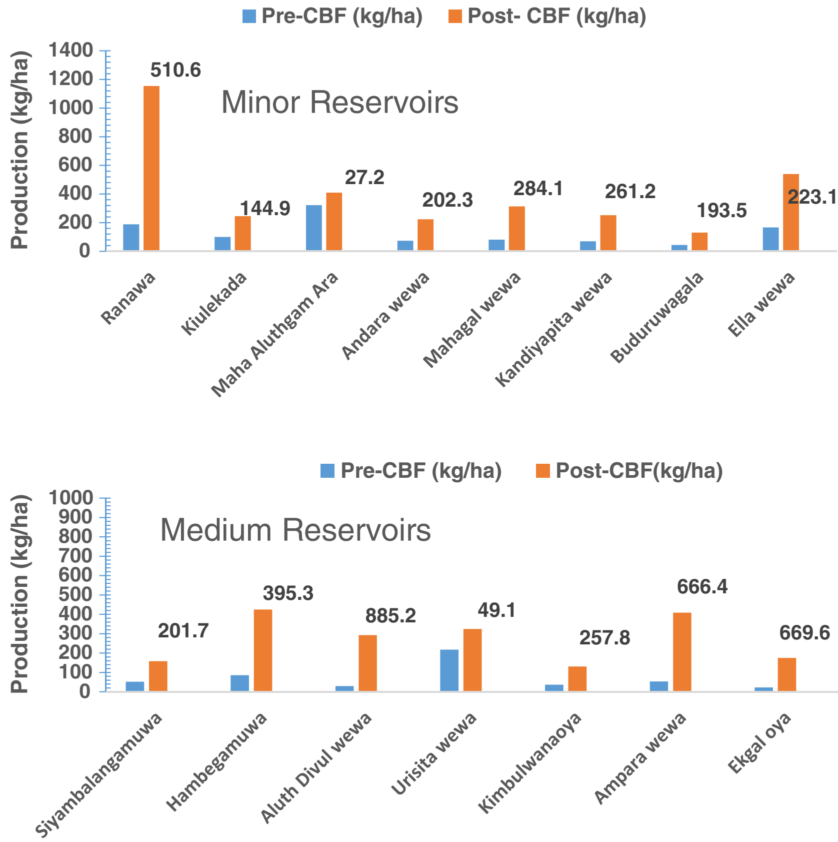

Fig. 5 Fish yield pre- and post CBF in selected minor (non-perennial reservoirs; see Brohier 1934 for definition) and medium sized reservoirs in Sri Lanka. The values provide the observed percent increase in production from pre- to post- CBF (redrawn from Chandrasoma et al. 2015)

Suitability of CBF as a development measure

Food fish supplies, as with the other staples of the world need to increase appreciably from the present levels, if they are to meet the projected increases in consumption rates and population (Committee on World Food Security 2014). Fish is the most important animal protein source for developing countries, accounting for approximately 30 % of the total intake. It is very unlikely that the food fish supplies from traditional sources, in particular marine capture fisheries, can be increased any further (Froese et al. 2012). Over the last three decades or so, intensive aquaculture developments, primarily in the developing world, in the Asia-Pacific region countries, spearheaded by PR China, contributed to bridging the gap between supply and demand for food fish (Subasinghe et al. 2009; FAO 2011a, b; Subasinghe et al. 2012). Although intensive aquaculture, the "new kid on the block" from food production and food security viewpoints (De Silva and Davy 2010), has enabled food fish supplies to be predominantly of farmed origin, like all other staples (De Silva 2012) its ability to maintain the past development trends are being increasingly questioned. This arises from the perceived unaffordability of the drain on relevant primary resources, physical and biological, and negative impacts on environmental sustainability.

It is in the above context that aquaculture practices, which do not necessarily depend on excessive external inputs and use existing primary water resources for the secondary purpose of producing food fish, have to be explored. CBF practices conform in most ways to such criteria. The suitability of CBF as a plausible development strategy can be highlighted as follows:

- CBF are practised in existing water bodies and in compliance with other users of the water resource and are a secondary and a non-consumptive user of the resource.
- The great bulk of CBF occur in rural areas and will therefore directly benefit rural communities that tend to be relatively impoverished.
- The only external input in CBF is seed stock (except in the rare instances when grass carp are stocked and are fed grass); a proper planning of broodstock management strategies to comply with seed stock requirements will ensure minimal impacts on genetic diversity and biodiversity.
- CBF are often community managed practices with agreed benefit sharing procedures. CBF practices often tend to use community organisations that have been established and stood the test of time, e.g. for managing water resources for downstream rice cultivation. The effectiveness of community management results in the generation of synergies within rural

communities that have significant positive societal impacts, beneficial to all.

- Exceptions occur in some countries such as for example Vietnam; in Vietnam small water bodies suitable for CBF are leased out by the authorities to individuals and/or groups of individuals who will be the beneficiaries.
- CBF are very low capital cost practices, which are attractive to developing country governments and relatively easy to implement. Some developing country governments, for example Sri Lanka and Lao PDR, have amended and/or introduced relevant legislation to facilitate CBF adoption and development.
- All in all, as CBF are environmentally friendly and require minimal external inputs, they are therefore likely to be sustainable.

CBF is an activity conducted in natural or quasi-natural environments and will therefore be subject to the vagaries of the weather. Future CBF developments will, therefore, have to take into account the potential impact of climate change. This is particularly so as ideally CBF is conducted in small water bodies, which can be subjected to major fluctuations of water levels and consequently the stocking and harvesting strategies have to be managed accordingly. Equally, within a geographical region, with comparable micro climates, harvesting will be conducted within a narrow time frame, when the water levels recede. Consequently, there could be a glut of fish in a given area at a given time causing reduced farm gate prices. Avoiding this will require careful planning,

Management regimes for CBF

CBF almost always uses water resources not primarily created for fishery related activities; these cater mostly to downstream agricultural activities and communal uses for bathing, washing and for livestock etc. In general, water management for downstream agricultural activities are well regulated and implemented through committees constituted for this purpose.

In Laos, for example, persons from the water management committee for downstream rice paddy cultivation who are willing to be engaged in fishery activities are given the purview of developing the latter (Saphakdy et al. 2009; Phomsouvanh et al. 2015). As all activities benefit the community as a whole conflicts of interests are minimised. Similarly, in Sri Lanka, persons overseeing fishery related developments are chosen from among the village committees constituted for downstream agriculture activities in the command area under the purview of the Agrarian Services Department (Kularatne et al. 2009). On the other hand, in some countries (e.g. Bangladesh) the management practices that are put in place may come to be dominated by the more powerful and richer persons of the community, leading to conflicts and impacting on production and social inequality (Valbo-Jørgensen and Thompon 2007). In countries where an open access policy is in operation, such as in Cambodia, CBF developments have to be conducted in a manner that are not in conflict with the policy, such as through the use of conservation zones in the water bodies for nursing the seed stock to an appreciable size (Srun et al. 2013; Srun and De Silva 2015).

Potential augmentation to food fish supplies from CBF

In the previous sections, the importance of CBF as a development strategy has been demonstrated, and the countries that have embarked on it have witnessed significant successes leading to an augmentation of food fish. Importantly, these gains have mostly benefitted rural communities in developing countries who tend to be poor relative to other sectors (Yunus 2007) and whose major animal protein intake is fish. Over the last decade or so CBF practices have been consolidated through extensive R & D efforts in key countries and key areas. Accordingly, the choice of water bodies for implementation of CBF, the most appropriate species combinations and stocking densities are now known. Importantly, unlike intensive aquaculture, CBF require relatively limited technical expertise, are easily adoptable by enthusiastic village communities and require neither extensive training nor capacity building.

The available statistics clearly indicate that CBF contributed nearly 4 million t/ yr to aquaculture production in China. Similarly, there is quantitative evidence to show that, in Sri Lanka, CBF have been pivotal to increasing inland fish production; moreover, its popularity has stimulated the growth of other ancillary sectors such as fry to fingerling rearing and has created livelihood opportunities in rural areas.

It has been estimated that there are nearly 67 million ha of small water bodies in Asia alone that are primarily irrigational (FAO 1999). Small water bodies are ideal for CBF development. If 20 % of this acreage were mobilised for CBF in the ensuing decade, with the aim to achieve 50 % of the mean yield achieved by CBF practices in China (1746 kg/ha/yr; Wang et al. 2015), food fish production would be increased by approximately 11.7 million t /yr. It should, however, be pointed out that computation based on the assumption that 50 % of the mean production in China is not unrealistic in the light of comparable production levels that have been achieved in CBF practices in other countries such as Laos, Sri Lanka and Vietnam as cited previously.

Alternatively, if 11.7 million t /yr of fish were to be produced through intensive aquaculture it would require a minimum of 17.55 million t of feed (at the very conservative average FCR of 1.5 (FCR=Food Conversion Rate is the ratio of dry food material required to increase the biomass of the stock by unit weight). Assuming that the feed has only 20 % fish meal the wild fish resource needed to produce the feed needs would be approximately 20 million t. This would be a considerable drain on wild fish resources in a climate where the use of fish meal and fish oil in aquaculture is being hotly debated on ethical and sustainability grounds (Naylor et al. 2000; Aldhous 2004; Cao et al. 2015).

CBF has the potential to be extended into Africa and South America, and also possibly cater to the needs of indigenous rural communities such as in Australia. The overall investment costs for a significant increase in food fish supplies through CBF would be relatively small and affordable to most developing economies. For adoption and development of CBF what is most needed is the political will. The main bottle neck to such development would be limited seed stock. However, the artificial propagation of commonly used species is well developed, and most facilities are already in place. The bottle neck can be overcome through encouragement of the development of fry to fingerling rearing facilities as a separate ancillary sector, as in Sri Lanka, creating more livelihood opportunities and ensuring sustainability.

Sustainability of CBF

In the foregoing sections the *modus operandi* of CBF, its benefits and its impacts on food fish availability have been addressed. It will be imperative to ensure long term sustainability of CBF practices. As CBF are a community managed practice one of the key factors that will contribute to ensuring its sustainability is to maintain communal harmony through the engagement of all stakeholders in the practices and the ensuing benefits, which should be shared in an equitable and/or an agreed manner. CBF activities are almost totally dependent on the elements, primarily the annual cycle of precipitation. Therefore, it is also important for the communities engaged in CBF to be alert to possible changes in the hydrological cycle. These could cause loss of a cycle or even result in complete loss of stock. Communities should be prepared to face such unusual events and not be deterred in resuming CBF activities when normality returns.

A key to sustainable development is to have minimal impacts on biodiversity (UNEP 1987; CBD 1994). The probability of escape from CBF activities may be higher than in conventional aquaculture. Escapees could mingle with wild counterparts and affect genetic diversity of the latter, particularly if the escapes are alien species (Nguyen 2015). Use of alien species in CBF and their escape into the wild could also affect biodiversity. All these factors may affect long term sustainability either directly and/or indirectly. It is therefore imperative that in CBF seed stocks used are sourced from hatcheries that practice proper broodstock management and are disease free and the use of alien species is kept to a minimum (Nguyen 2015).

Conclusions

Because of increases in population and consumption, there is a greater requirement for fish but it is only in the last 5 years that our dependence on a hunted supply has changed to a predominantly farmed supply, like other staples. However, a complete transformation to a farmed supply of food fish is unlikely, owing to the considerable stocks in the oceans and seas. CBF have already proved to be an effective means of augmenting food fish supplies in some countries. A concerted effort in adopting the technique on a wider scale could do much to satisfy the protein needs of the developing world.

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