Potential of culture-based fisheries in Indonesian inland waters

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Abstract: Fish stocking in Indonesian lakes and reservoirs has been conducted for a long time. Since 1999, culture-based fisheries (CBF) practices based on scientific evidence such as using suitable fish species, consideration of the primary productivity, stocking density, economic evaluation and community participation, have been conducted in some reservoirs and lakes and have showed encouraging results. Potential fish yield of a water body for CBF development is one of the important factors in determining its success. Potential fish yield of some lakes and reservoirs was estimated using a morpho-edaphic index or primary productivity approach, and the water bodies were classified based on morpho-limnological characteristics. Estimated potential fish yield of small reservoirs/lakes with an area between 1.0-200 ha showed the highest potential with an average yield of 2835 ± 623.6 kg/ha/yr compared to the others of lager area. In the future, therefore, development of CBF was highly recommended and prioritised in small reservoirs with an area less than 200 ha, mostly distributed in Sumatera, Java, and Nusa Tenggara with more than 2,000 reservoirs. However, about 80% of those reservoirs were categorised as idle presently.

Key words: Potential fish yield, lake, reservoir, culture-based fisheries, morpho-edaphic index.

Introduction

Development of inland fisheries in Indonesia is one of the strategies for increasing food fish production, providing employment and food security to communities deprived of easy access to food fish resources. In this context culture-based fisheries (CBF) are recognised as a strategy suitable for adoption in Indonesian inland waters.

CBF are defined 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 (FAO 2011). CBF 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. The natural processes of the water body will determine its potential.

This paper discusses the potential of inland waters, especially Indonesian lakes and reservoirs for CBF development. CBF development strategies in these water bodies based on the application of the lesson learnt from CBF elsewhere are also described.

Materials and methods

Data on the status of limnology, fish resources and fisheries, stock enhancement and CBF of Indonesian inland waters were collected from the literature. Potential fish yields of some lakes and reservoirs were estimated using primary productivity and or the morpho-edaphic index (a ratio between conductivity and mean depth) approach (Oglesby 1982; Downing et al. 1990; Moreau and De Silva 1991; MRAG 1995; Kartamihardja 2009).

Lakes were classified into volcanic, tectonic-volcanic and floodplain lakes, while the reservoirs were classified into multipurpose, irrigation, and small or village reservoirs with an area less than 200 ha. Data on potential fish yield for each water body was plotted against area following the above classification.

Recommendations for prioritising water bodies suitable for CBF development were analysed through several criteria, such as CBF principles (De Silva et al. 2006); primarily, potential fish yield, relative easiness to manage, availability of fish seed and community preferences, opportunity on establishment of management institution and expected outcome impact on socio-economics of the community and sustainability of CBF.

CBF development strategies were formulated based on consideration of lessons learned on the successful CBF practices in Indonesia and opportunity of success and their impacts on socio-economic and livelihoods as well as welfare of the community.

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Results and discussion

Limnological characteristics of inland water resources

Indonesia has a vast area of inland waters covering 13.85 million ha (Sukadi and Kartamihardja 1995), which consists of river ecosystems and floodplains (12.0 million ha), lakes (1.8 million ha), and man-made lakes (reservoirs; 0.5 million ha). The total area of inland waters is about 65%, 23%, 7.8%, 3.5% and 0.7% in Kalimantan, Sumatera, Papua, Celebes and Java, Bali and Nusa Tenggara, respectively, but these proportions change annually because of seasonal water fluctuations (Sarnita 1986).

There are 5,590 major rivers 94,573 km in length and 65,017 tributaries. Indonesia also has 840 lakes, 162 major reservoirs and 735 small reservoirs and lakes ("situ" or "telaga") (Ministry of Public Work–Directorate General of Waters Resources 2013). Based on the areas, small reservoirs are classified into those between 50 and 200 ha (average of 75 ha), irrigation reservoirs between 2 and 50 ha (average of 15 ha), and small ponds between 0.50 and 2 ha (average of 1.0 ha). Most of the small reservoirs are distributed in Sumatera, Java, and Nusa Tenggara. Until recently, the small reservoirs have not been utilised for fisheries development.

Inland waters in Indonesia are also used by other sectors, such as agriculture, forestry, hydroelectric power and mining, and as water sources for home and industrial purposes, transportation (including navigation) and tourism. These multipurpose uses of inland waters compete with fisheries activities, in relation to the structural modifications, and quality and quantity.

Fish and fishery resources of inland waters

FishBase (2011) records indicate that the number of fish species inhabiting inland waters of Indonesia amount to 1,169. Kottelat and Whitten (1996) stated that the number of freshwater fish species in Indonesia to be approximately 1,300 species. These authors suggested that the biodiversity of Indonesian freshwater fish species was the second richest in the world next to that of Brazilia. The discovery of new species and revision of existing species continues (Hadiaty and Siebert 1998 2001; Ng et al. 2004; Page et al. 2007).

Indonesia is divisible into two ecological regions; western Indonesia is more influenced by the Asian mainland fauna, and the east is more influenced by Australasian fauna. Zoo-geographically, fish resources of inland waters of Indonesia are divided into fish that inhabit the Sundaland, Wallacea zone and Sahulland, which are inhabited by more than 1,000 fish species (Kottelatet al. 1995). In the Sundaland more than 358 species of the order Ostariophysi and Labyrinthici dominate inland open waters, particularly in Sumatera and Kalimantan (Ondara 1982).

There are about 310 species of fishes recorded from the rivers and lakes of Wallacea, 75 of them being endemic. Although little is still known about the fishes of the Moluccas and the Lesser Sunda Islands, 6 species are recorded as endemic. In Sulawesi, there are 69 known species, of which 53 are endemic. The Malili lakes in South Sulawesi, with its complex of deep lakes, rapids and rivers, have at least 15 endemic thelmatherinid fishes, two of them representing endemic genera, three endemic *Oryzias*, two endemic halfbeaks, and seven endemic gobies.

Most of the species that inhabit inland waters of Indonesia are riverine, and only a few are lacustrine. This condition is one of the factors that is thought to be responsible for the relatively low fish production in lakes and reservoirs. Species that dominate lakes and reservoirs are generally of the cyprinid family such as *Puntius*, *Barbonymus*, *Hampala*, *Mystacoleucus*, *Osteochilus*,the silurid family such as *Mystus* and *Channa*, and cichlids, *Oreochromis mossambicus*.

FAO (2014) reported that globally, about 13% of the total inland fishery products (although in reality probably higher) is consumed by the local communities. For the people in Southern Sumatra, Kalimantan and Sulawesi, freshwater fish consumption is high, and for the local communities it is their main source of animal protein and micro-nutrients. Among Asian countries Indonesia is ranked 6th in inland fish production. Inland waters contribute 16% to the total fish production of Indonesia. In the period of 2005-2012, total fish production from capture fisheries and aquaculture (cage culture) of Indonesian inland waters were between 474,680-1,026,940 tonnes (average of 710,101.6 tonnes) (MMAF2012), as presented in Figure 1. The fish production from both activities tended to increase from year to year. In Indonesia, the fish production of CBF was reported under capture fisheries and consequently production data for CBF is not evident in the total fisheries production.

Stock enhancement and culture-based fisheries

Increasing fish production in reservoirs and lakes can be done through the application of appropriate stock enhancement practices, such as culture-based fisheries (CBF) technology. The purpose of the technology application is to improve the quality and quantity of fish production in the water body by utilising the natural food resources and habitats (niche ecology) which are un- or under-utilised. Since 1999, stock enhancement

Figure 1. Fish production of the Indonesian inland waters 2005-2012.

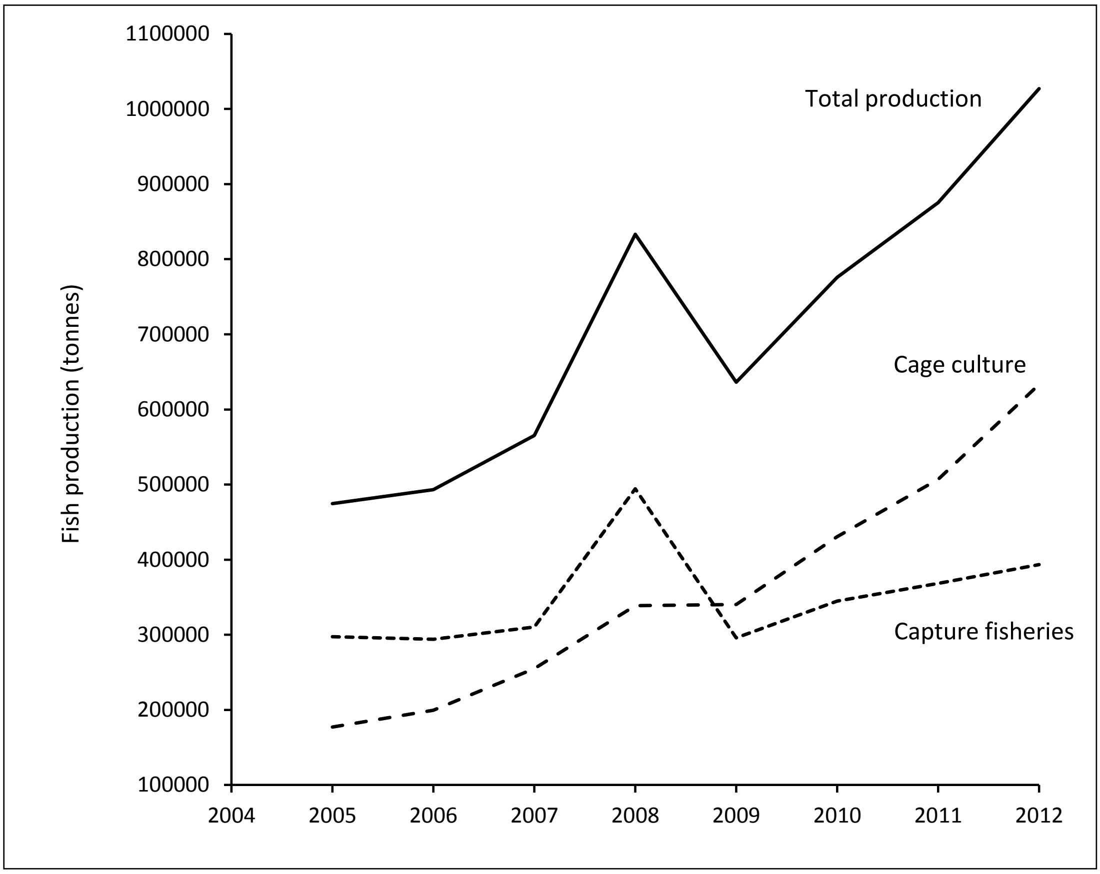


Table 1. Fish yield of some lakes and reservoirs before and after implementation of stock enhancement and CBF.

Water Body	Area (ha)	Species	Yield (kg/ha/yr)		Remarks
			Before	After	
Toba Lake	112,000	*Mystacoleucus padangensis*	22-28	350-400	Breed naturally
Wonogiri R.	7,800	*Pangasianodon hypopthalamus*	26-35	59-62	Breed naturally
Malahayu R.	275	*P. hypopthalamus*	60-75	105-129	Do not breed naturally
Darma R.	400	*Macrobrachium rosenbergii*	75-123	99-128	Do not breed naturally
Jatiluhur R	8,300	*Chanos chanos*	27-32	178-181	Do not breed naturally

of Indonesian lakes and reservoirs was generally based on scientific data and information on productivity and ecological niches of the waters body, structure of fish communities, life cycle and biology of the stocked fish (Kartamihardja 2007). Examples of successful fish stock enhancement and CBF in some lakes and reservoirs are presented in Table 1.

In 2003, bilih fish (*Mystacoleucus padangensis*), a fish endemic to Lake Singkarak in West Sumatra, were introduce to lake Toba in North Sumatra. This species grows and breeds naturally and now inhabits the pelagic area of the lake (Kartamihardja and Purnomo 2006). Since 2005 bilih production has increased from 653.6 to 30,000 tonnes in 2010, and has since increased sharply reaching 40,000 tonnes in 2012 (Kartamihardja and Sarnita 2010; Wijopriono et al. 2010).

In the period 1999-2002, about 36,450 seed of Siamese catfish (*Pangasianodon hypophthalmus*) have been introduced into Wonogiri Reservoir in Central Java and since 2003 the catfish production has increased gradually. In 2004, the Siamese catfish yielded 112,215 tonnes valued at 785.5 million rupiahs (IDR)[1] adding to the income of each fisher approximately 1.2 million rupiahs (IDR) per year (Kartamihardja and Purnomo 2004). The Siamese catfish grow fast and its fecundity at a standard length of 67.0-82.7 cm and weight of 3,000-5,500 g ranged from

1. IDR 10,000= 1 US$.

271,700–1,177,250 eggs (Adjie et al. 2006). The Siamese catfish can spawn naturally and the seed are distributed in the mouth of Keduwang River, one of the inlet rivers. In the period 2005-2010, catfish production levelled off, reaching between 142.925–191.210 tonnes. This indicated that the rate of recruitment from natural spawning was lower than that the rate of exploitation (Kartamihardja et al. 2011). In December 2011, about 400,000 fingerlings of Siamese catfish 5.0-7.5 cm in standard length and 15-20 g were also stocked in Malahayu reservoir (Central Java). The catfish grew fast, reaching an average of 300-600 g and standard length between 25-38 cm after 6 months (Kartamihardja 2012).

Giant freshwater prawn (*Macrobrachium rosenbergii*), introduced into Darma Reservoir, West Java in 2003, yielded 337.65 kg with a value of 13.5 million rupiahs (IDR) in 2004, even though the seed stocked was only 26,500 tails or 26,5% from the optimum amounts of stocking (Kartamihardja etal. 2004). If the prawn stocking was done optimally, the production value of 70-140 million rupiahs (IDR) per year could have been attained and bringing an additional income for 120 fishers.

CBF of milk fish, *Chanos chanos*, has been conducted in Jatiluhur Reservoir, West Java in 2008-2009. Fingerlings numbering 2 million (in 2008) and 4 million (in 2009) were stocked in the reservoir. Milk fish production reached 65 tonnes in 2009 and 180 tonnes in the period 2011-2012. Milk fish stocking also aimed to mitigate the impact of intensive cage culture, especially to control phytoplankton blooming (Abery et al. 2005; Maskur et al. 2010). The abundance and biomass of phytoplankton decreased significantly one month after stocking. The nitrogen and phosphorous contents also decreased significantly, and the frequent algal blooms and mass fish kills have since being avoided (Kartamihardja 2012). In August 2014, about 300,000 milk fish seed were also stocked in Sempor Reservoir (275 ha; Central Java). The milkfish grew to an average weight of 260g per fish after 3 months of stocking (Umar 2014 pers. Com.).

The success of stocking fish in the waters bodies of area greater than 500 ha showed that catches of the CBF was high if the fish species introduced could fill the empty niche and be able to breed naturally.

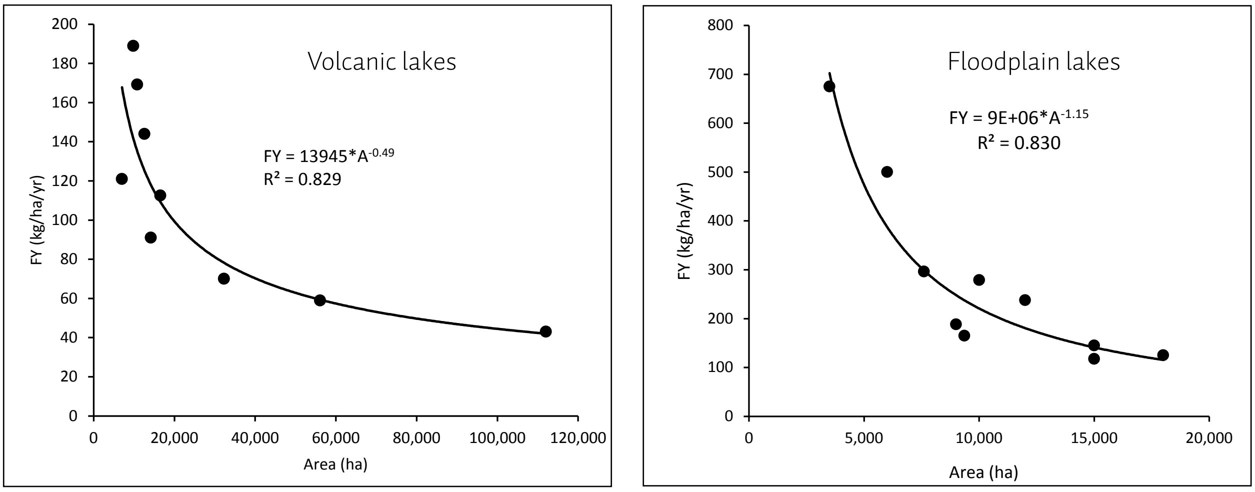
Potential and suitable water bodies for culture-based fisheries

Indonesia has thousands of lakes and reservoirs of which the major lakes are distributed in Sumatera, Kalimantan, Sulawesi and Papua. Most of the major lakes were formed by volcanic or tectonic forces or a combination of both, or river action as floodplain lakes. The major reservoirs (about 65%) are mostly situated in Java, while the small lakes and reservoirs or village reservoirs are mostly situated in Sumatera, Java, and Nusa Tenggara (Table 2). The number of small reservoirs has increase due to development of reservoir for collecting water in the rainy season, especially in Eastern Indonesia which has a long dry season. Most of the small reservoirs are utilised for agriculture, irrigation and drinking water for cattle.

Table 2. Distribution (numbers) of Indonesian small waters bodies.

Name of island	Lakes	Reservoirs	Total
Sumatera	329	217	546
Java	327	342	669
Bali	14	29	43
Nusa Tenggara	27	586	613
Sulawesi and Maluku	37	151	188
Papua	2	16	18
Indonesia	736	1,341	2,077

Figure 2. Relationship between potential fish yield (FY) and area (A) of lakes.



Potential yield of major lakes

Estimation of potential fish yield of the major lakes, classified into volcanic or tectonic-volcanic lakes and floodplains lakes with water surface area between 10,000-110,000 ha and 3,000-20,000 ha, respectively, was based on geo-morphological characteristics and productivity (Figure 2). The tectonic-volcanic lakes are deep, the littoral zone is followed by a steeper zone and are oligotrophic to mesotrophic, whereas flood plains lakes are relatively shallow, have greater seasonal water fluctuations and are mesotrophic to eutrophic (Lehmousloto and Machbub 1977; Kartamihardja 2006; Sulastri 2006). The estimated potential fish yields of the volcanic lakes were between 43-189 kg/ha/yr (average of 111 ± 50.1 kg/ha/yr), and of the floodplains lakes were between 118-675 kg/ha/yr (average of 266 ± 188 kg/ha/yr).

Potential yield of reservoirs

Estimation of potential fish yield of reservoirs was done by categorising the reservoirs as: (a) multipurpose reservoirs with an area of >1,000 to 10,000 ha; (b) irrigation reservoirs with an area of >200-500 ha and (c) a small reservoirs with an area range from >1.0-200 ha. The estimated fish yield of the three groups are presented in Figure 3. The multipurpose, irrigation and small reservoirs have potential fish yields of between 239-320 kg/ha/yr (average of 273.0 ± 27.4 kg/ha/yr), 288-455 kg/ha/yr (average of 364.1 ± 51.9 kg/ha/yr), and 1,621-3,965 kg/ha/yr (average of 2,835 ± 623.6 kg/ha/yr), respectively. The small reservoirs have the highest productivity (primary productivity of phytoplankton based).

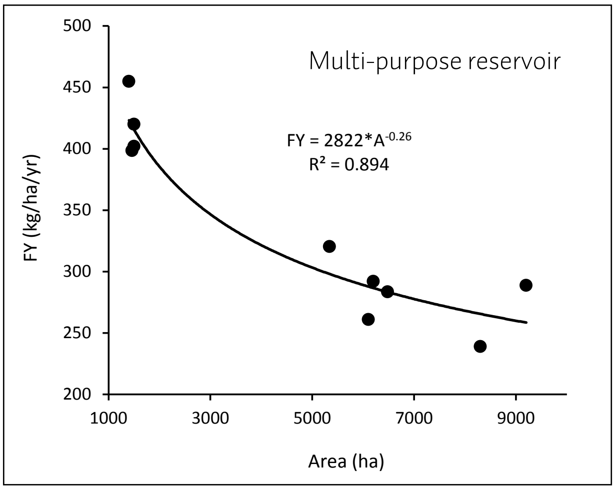
The relationship between potential fish yield and area of lakes and reservoirs can be utilised for optimisation of stocking density and expected fish production of those water bodies.

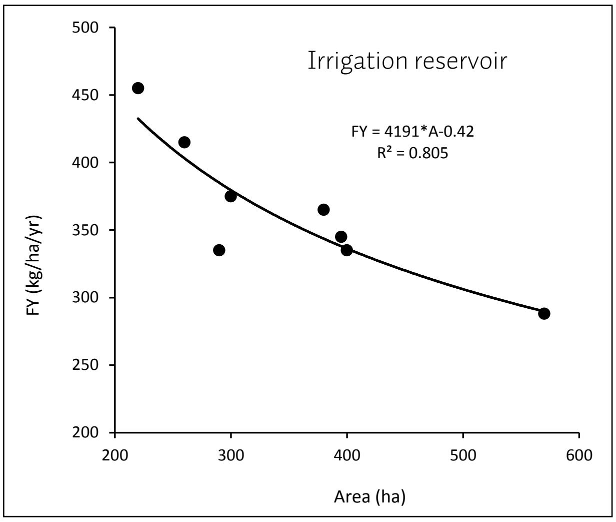
Water bodies suitable for CBF

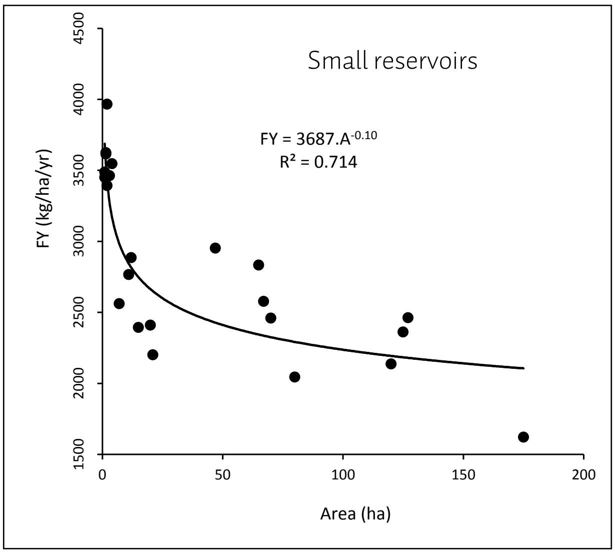
In principle, all reservoirs and lakes are suitable for the development of CBF, however, in this case the CBF development will be focused on waters bodies such as small reservoirs/lakes with an area of less than 200 ha for the following reasons:

- Small reservoirs have the highest potential fish yield compared to the others
- Small reservoirs can be managed as a big fish pond so that the area is easy to control and manage properly
- There are many small reservoirs situated in the rural area that have not been utilised for fisheries development yet

Figure 3. Relationship between potential fish yield (FY) and area (A) of the reservoirs.







- Fish seed optimally needed for stocking is relatively easily procured
- Risk impacts of stocked fish on native fish diversity as well as their genetics is relatively negligible
- Fish production from CBF is primarily aimed for improving nutrition, food security and additional income for the rural people that live in the vicinity
- The fisher groups are an important management unit of CBF is relatively small in number and their ability as well as their capability are easily established and improved.
- Conflicts between the users of the waters bodies can be minimised because the fish stocked do not degrade the waters and not necessarily interfere with the other functions of a reservoir.

Development of CBF in small reservoirs should include technical considerations on ecological, socio-economic, and institutional aspects. From the ecological perspective, the water body should have good water quality for fish life, high natural food resources or high potential fish yield, and the water volume available throughout the year or at least eight months until the fish could grow to table size. Seed stocks should be available and procured easily and be species of economic value, preferred by the communities, and feed low in the trophic chain (plankton feeders, herbivores, or omnivorous), can utilise natural food resources, and non-invasive or not negatively impact on native fish species.

Some technical considerations in the implementation of CBF are fish seed supply, preconditions and acclimatisation, handling and transportation, stocking density, size or age of seed stocked and time as well as stocking mechanism.

Preconditioning and acclimatisation are needed for stocked species to adapt to a new aquatic environment and ensure a high survival rate. For example, stocking prawns in the Darma Reservoir and Siamese catfish stocking in the Jatiluhur, Wonogiri and Malahayu Reservoirs is done after the prawns and the Siamese catfish have beenreared in a net cage in the reservoir for a month (Kartamihardja et al. 2004).

In the implementation of fish stocking programs, potential risks that will arise in relation to genetics, ecological and socio-economic environments should be anticipated in advance. In other words, the implementation of stocking should refer to the management of fisheries in charge (Code of conduct for responsible aquaculture/fisheries) as well as FAO's "Blue Growth" - a coherent approach for the sustainable, integrated and socio-economically sensitive management of inland waters, focusing on capture fisheries, aquaculture, ecosystem services, trade and social protection of coastal communities. The Blue Growth framework promotes responsible and sustainable fisheries and aquaculture by way of an integrated approach involving all stakeholders (FAO 2014).

Development strategy for culture-based fisheries

The problems faced in the implementation of CBF in waters bodies in Indonesia among others were:

- An understanding of science and technology of CBF by officers and the community, and the need for socialisation.
- In general, results of scientific studies indicated that CBF implemented in some water bodies were not carried out correctly, and protocols used were not adequate and clear.
- Monitoring and evaluation of the CBF implementation to determine the success or failure of the application of these technologies were not done.
- Regulation and institutions in the management of fisheries resources are not yet available.
- Management of fishery resources has not involved public participation.

With implementation of a strategic research phase in order to solve these problems, CBF developments in Indonesian waters bodies are expected to achieve a common goal, namely the establishment of the maximum utilisation of resources and its sustainability for the welfare of the society. The steps that must be done in the application of CBF technology are identification of water bodies, selection of the fish species, identification of fisheries activities and community engagement. Monitoring and evaluation of CBF should also be factored into their application.

Determining the water body productivity should include take into account water volume availability, water quality, the type and abundance of natural food resources, native fish species composition, and estimation of potential fish yield. Selection of the fish species to be stocked should include the number and quality of seed, aspects of biology, especially food and feeding habits and reproduction and habitat (mainly if the water body inhabited by native and endemic species), economic value, community preferences, and seed should be available and easy to obtain from hatcheries.

Identification of fishery activities include the number of fishers, the type and quantity of fishing gear, the species, composition and quantity of the fish catch are conducted if the fisheries activities already exist. Identification of communities around the water bodies include the amount or availability of fishing groups, monitoring and surveillance by the society or groups and other fisheries groups.

Identification of the costs required for the fish stocking activity, monitoring and evaluation of success should be anticipated before implementation of CBF. Monitoring activities should be carried out from the beginning of planning, during and after the application of CBF technology, and evaluation of the results of monitoring conducted to assess the success or failure of the application of CBF.

Conclusions

Indonesia has a large inland waters resource with thousands of small lakes and reservoirs which are suitable for CBF development. Moreover, the waters bodies have high potential yields, but those water bodies have not been utilised. CBF conducted in some lakes and reservoirs showed a significant increases in fish yield and the rural income of the community that live in the vicinity of the waters bodies. In the future, the development strategy for CBF should be based on scientific evidence, including identification of the water body productivity, providing fish seed/fingerling of herbivorous/omnivorous species preferred by the communities, optimisation of fish stocking density, development of fishing technology and market systems, training on fish processing and capacity building of fisheries institutions and management, and coordination with the lakes/reservoirs authorities. It is estimated that the best practices of CBF development in small lakes/reservoirs in Indonesia could result in yields exceeding one million metric tonnes.

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