Genetic considerations in culture-based fisheries development in Asia

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Abstract: Culture-based fisheries (CBF) is a practice in which, in general, fish are stocked in small water bodies that are unable to sustain an artisanal fisheries through natural recruitment. CBF has gained popularity in recent years, due to its simplicity in terms of inputs and management and cost effectiveness. Traditionally, in the Asian region, exotic species are used, but countries newly embarking on CBF prefer the use of indigenous species. The shift towards the use of indigenous species was believed to counter negative impacts, perceived or otherwise, brought about by use of exotic species. However, it is also true that hatchery-produced fingerlings that escape can also pose a potential threat to genetic diversity and integrity of their wild counterparts.

At the Regional Workshop on "Culture-based fisheries development in Asia" (this volume), it was clear that the debate on the use of exotic versus indigenous species is still an ongoing topic. This paper entails the pros and cons in the use exotic vs. indigenous species in CBF and steps to be followed when decisions are made on species choice for CBF. The ultimate goal is to improve production whilst maintaining genetic diversity and integrity of the surrounding ecosystems.

Key words: *Biodiversity, broodstock management, genetic management, captive breeding, alien species, indigenous species*.

Introduction

Culture-based fisheries (CBF) is a practice in which fish are stocked in small water bodies which are unable to sustain an artisanal fisheries through natural recruitment. It is often a secondary user of water resources and is seen as an important strategy to improve food security in rural areas of developing countries (De Silva 2003, De Silva et al. 2006a, Amarasinghe and Nguyen 2010). In earlier stages of development, CBF in countries for example Sri Lanka and Vietnam were largely dependent on exotic species such as tilapia, and major Indian and Chinese carps due to availability of fingerlings as well as a lack of suitable fast growing indigenous species (Amarasinghe and Nguyen 2010). The current trend, however, is moving towards including indigenous species for stocking. This change is driven by the need to mitigate the negative impacts of alien species, perceived or otherwise (Sverdrup-Jensen 2002, Mattson 2005, Ingthamjitr 2009), especially in some of the Mekong riparian countries such as Lao PDR and Cambodia.

The preference to use indigenous species in CBF brings about new challenges. CBF, as any other food production sector, needs to be practised in a manner that minimally impacts the environment, including genetic diversity of natural fish populations. Fingerlings used for stocking are often derived from hatcheries that produce seed for aquaculture purposes as there are no hatcheries dedicated to CBF or stock enhancement in the region. Hatchery-produced fish are known to be more adapted to hatchery conditions and therefore less fit in the wild (Araki et al. 2008). Water bodies that are suitable for CBF are often prone to flooding and stocked fish has the potential and a greater chance to escape and interbreed with their wild counterparts, when compared to intensive aquaculture practices in ponds, cages among others. This will potentially result in reduced fitness and adaptability if wild stocks (Hindar et al. 1991, Waples and Do 1994, Araki et al. 2008).

Consultation with local communities often take place when choosing species for CBF. Species are selected based on local preferences, seed availability and ability to reach a harvest size before the onset of the dry season (De Silva et al. 2006a). Exotic species used for CBF in the Asian region are mainly Indian carps (e.g. rohu, *Labeo rohita*; mrigal, *Cirrhinus cirrhosus*; and catla, *Catla catla*), Chinese major carps (e.g. silver carp, *Hypophthalmichthys molitrix*; bighead carp, *H. nobilis*; and grass carp, *Ctenopharyngodon idellus*), and Nile tilapia (*Oreochromis niloticus*). Of all exotic species used for aquaculture, species that are commonly used in CBF have shown no impacts on local environment (De Silva et al. 2006b), except the African walking catfish (*Clarias gariepinus*) (Na-Nakorn et al. 2004). Species that can interbreed and produce viable off spring with local species, such as the African walking catfish, is therefore discouraged from being used in CBF and not discussed further in this paper.

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The aims of this paper are to discuss issues pertaining to genetic management of species used in CBF. These species can be categorised into two groups: exotic species that do not interbreed with local species and indigenous species. Objectives of genetic management for these two groups of species are different: optimising productivity for the former and mimicing natural level of genetic diversity and minimising adaptation to hatchery conditions in the stocked materials for the latter.

Genetic considerations

Existing exotic species that do not interbreed with local species

Species that fall into this category include tilapia, major Indian and Chinese carps. Artificial propagation of these species has been established for many decades and fingerlings are often readily available. The successes in artificial propagation of these species possibly paved the way for initial expansion of intensive aquaculture in tropical Asia in the early growth phases of the sector, and still continues to make the highest contribution to cultured food fish production globally (FAO 2012). The aim of genetic management for species in this category is to maximise productivity. Water bodies used for CBF are often non-perennial[1], and stocked fish need to reach a marketable size before water levels recede appreciably. Fast growing fish are therefore needed. It is unfortunate that fish selected for fast growth in an aquaculture environment do not always perform as well in CBF due to its reduced adaptability to feed on naturally produced food organisms and competition for resources with other species. For example, Genetically Improved Farmed Tilapia (GIFT) was outperformed by feral tilapia in reservoirs in Sri Lanka (Wijeynayake et al. 2007).

Other technologies could be used to develop fast growing strains included triploidy and monosex. These technologies have proven effective in some species, for example triploid oysters (Stanley et al. 1984) and monosex tilapia (Mair et al. 1997).

Indigenous species

Recently artificial propagation of indigenous fish have been successfully conducted for many species. As a result, more indigenous species have been used for aquaculture and for stocking in natural waters. As mentioned earlier, the use of indigenous species in stocking may relieve the perceived issues brought about by exotic species, but the use of the former also brings to focus a new set of challenges. Fish, once domesticated and reproduced under hatchery conditions, results in reduced genetic variability (Hamasaki et al. 2010, Nock et al. 2011), changes in behaviour (Jonsson et al. 2003), and reduced fitness within one or two generations of captive rearing (Araki et al. 2008). Hatchery-produced fish once stocked in natural waters could become a major part of the fishery, for example up to 70% of silver barb (*Barbonymous gonionotus*) collected in Thailand waters were of hatchery origin (Kamonrat 1996). Genetic interactions between less fit hatchery-produced fish and wild stocks may result in reduced fitness of wild populations. As such, the aim of genetic management here would be to maintain the hatchery stock as comparable or similar to the wild stock as possible. To achieve this, the broodstock used for fingerling production should be as similar to the local wild fish as possible, and procedures in hatcheries should minimise the difference to wild processes.

Sustainable CBF practices should use fingerlings with a similar level of genetic diversity to wild stock. Choosing an appropriate source of broodstock is an important step. The best option here is to apply supportive breeding, a practice in which mature broodstock from local waters are caught and bred, and their offspring are released into the same area (Ryman and Laikre 1991). This practice prevents exogenous genes being introduced in to the local population. There is also evidence suggesting that hatchery stocks that use wild local fish for captive propagation generally perform better than non-local stocks (Araki et al. 2008), another reason justifying the use of local broodstock for breeding. An example of such a breeding program is Murray cod (*Maccullochella peelii*) breeding at the Fisheries Victoria Snobs Creek Hatchery, Australia, a hatchery dedicated to breeding fish for stocking. Mature wild caught males and females are kept in earthen ponds and spawned naturally (mostly monogamous). Larvae are reared to fingerling size (40-60 cm total length) in fertilised ponds before being released into the wild. Such practices have resulted in an increase in effective population size of the wild stocks (Ingram et al. 2011).

When the number of broodstock sourced from one place are inadequate to achieve production targets and there is a need to recruit broodstock from elsewhere, it is important to understand population genetic structure of the species. Introducing new stocks of the same species to local waters may result in changes in population genetic structure (Eldridge and Naish 2007, Marie et al. 2010, Horreo et al. 2011). Genetic DNA markers such as microsatellites have been extensively used for investigation of population structures and identifying management units. Some studies in the Asian region suggest strong population genetic structure in species that have been candidates for CBF such as mud carp, *Cirrhinus molitorella*

1. It should be noted that gradually CBF practices are being extended into non-perennial waters in the recent years (see Chandrasoma et al. this volume), and consequently the genetic management in CBF will become even more exacerbated and crucial.

(Nguyen and Sunnucks 2012), or for stock enhancement such as mahseer, *Tor douronensis* (Nguyen 2008), and as such the use of local broodstock is recommended.

It is understood that in the Asian region where CBF is gaining popularity, resources required to undertake population genetic studies are lacking and hence information on population structure of species of interest is often unavailable. Collaboration with better equipped laboratories for such a task is recommended. Otherwise, it is advisable that broodstock should be collected in proximity of the CBF site, or from water bodies with most similar habitats, and fish with similar life history and behaviour (FAO 2008).

When mature wild broodstock are not abundant, domestication is required to maintain a breeding population. In this case, a structured breeding program to maintain genetic diversity and avoid inbreeding of hatchery stock is required. Methods to achieve this are entailed in the FAO Guidelines for Responsible Fisheries (FAO 2008). These include:

- Minimise inbreeding: Inbreeding can be avoided by not mating closely related individuals. This can be achieved by tagging and maintaining a pedigree for all broodstock. When tagging of broodstock cannot be done, increased effective breeding number can be used to minimise inbreeding (below). FAO (2008) recommends for stocking, inbreeding level should be maintained below 0.01. The number of broodstock required depends on the number of generations the hatchery is designed to reach production targets, the sex ratio used and successful spawning rates. For example, in a close breeding population, i.e. no new genetic materials are introduced for 5 generations, assuming pair mating is applied, it requires 250 males and 250 females with 100% spawning rate to achieve an inbreeding level of 0.01. In reality spawning rates are lower than 100% and the number of male and female broodstock required in such a case are much higher.
- Maximise effective breeding number: This can be achieved by practising the followings:
  - Ensure many fish are spawned and maintain sex ratio as close to 1:1 as possible – This will improve the chance of all genetic materials to be passed to the next generation. This should be followed by improving technologies to enhance spawning, fertilisation, hatching and nursing rates. It is understood that most hatcheries would like to maintain a minimal number of broodstock and use a skewed sex ratio to reduced production costs, but in the long term this practice would result in an undesirable outcome.
  - Apply pedigreed mating (keep one daughter from each female and one son from each male to be broodstock for the next generation), or each parent leave the same number of offspring to be broodstock for the next generation.
  - Equalise the number of offspring from each parent pair to be broodstock for the next generation. This requires each family to be maintained separately until offspring can be selected for broodstock.
  - Milt among males should not be pooled prior to, or added in a sequential manner, during fertilisation – This is to avoid sperm competition and sperm from one male may fertilising most of the eggs, which reduces effective breeding number.
  - Stretch generation time – Lengthening the broodstock recruitment interval will slow down the inbreeding process.
  - Maintain separate breeding lines and then hybridise between these lines – This requires structured facilities and resources.
  - Apply factorial mating – Instead of breeding full-sib families, a factorial design could be used to improve effective breeding number.
  - Avoid selection –Selecting larger or better appearance fish will reduce the chance of smaller or less attractive fish passing their genes to the next generation, which reduces genetic diversity.
  - Influx new genetic material to the broodstock population regularly – It is suggested that if 10-15% new broodstock are introduced each generation, inbreeding can be drastically reduced. An example in this regard is the fish stocking programs in Myanmar, where hatcheries are licensed to recruit new broodstock from the wild periodically, based on the agreement with the government that a proportion of fingerlings produced should be released into public waters as part of the national stock enhancement programs (Aung et al. 2009).

Apart from ensuring genetic similarity between stock and local wild fish, hatchery procedures from breeding to nursing should mimic wild processes as much as possible (FAO 2008). For example, natural diets should be used rather than artificial feed, ponds are recommended instead of tanks, or stock younger fish which are less adapted to hatchery conditions than larger, older, fish. The latter recommendation however faces the paradox that larger fish survive better in CBF environment.

Conclusions

Given the importance of CBF in providing food security and livelihood of the rural poor, and its popularity as an "environmental friendly" practice due to low input requirements, responsible use of genetic resources should be considered. While improving productivity using better management practices, negative impacts on the environment should be minimised. This can be achieved by careful planning, incorporating conservation aspects in management of CBF together with technology development to improve productivity. A desirable outcome should be better livelihood for the rural poor and their surrounding environment is minimally impacted.

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