Production Priorities Overshadow Genetic Quality At African Fish Hatcheries

Many African tilapia have mixed parentage. These fish from a farm in Zambia have genes from Oreochromis niloticus, O. motermeri, O. andersonii, O. aureus, *and* O. macrochir.

Summary:

Based largely on FAO programs that address rural poverty, small-scale hatcheries have been developed in Africa to produce catfish and tilapia fingerlings. Production practices that fail to maintain genetic diversity, however, often limit the growth performance of the fingerlings. Growth rates up to 40% lower than those of wild fish potentially cost African farmers over U.S. $200 million a year.

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The importance of high-quality seed for aquaculture has been the focus of a number of development interventions in Africa, most notably by the Food and Agriculture Organization of the United Nations (FAO). FAO built large public-sector hatcheries in high-potential areas around the continent as models for development and sources of low-cost, high-quality fingerlings to spur the expansion of fish farming. Unfortunately, poor project design and the involvement of inefficient government management led many of these efforts to failure.

Aquaculture Addresses Poverty

A shift in public-sector support from aquaculture development for its own sake to aquaculture as a tool in rural poverty alleviation during the 1980s and 1990s led to the encouragement of small-scale, private hatcheries that could be operated in conjunction with extensive or semi-intensive growout systems.

Although not encumbered with government bureaucracy, small-scale hatcheries are seriously constrained by cash flow issues in a chicken-or-egg conundrum. There is no market for fingerlings without growth in the production sector, but there can be no growth in production without reliable sources of fingerlings.

Due to other input and technical assistance constraints facing aquaculture, the lag time between growth of production and availability of seed can be several years. Most small-scale hatcheries go out of business long before they have enough customers to make them profitable.

Small-Scale Success

There have been successes with small-scale, hatchery-led development, most notably in Madagascar, Malawi, Tanzania, and more recently, Cameroon. Where small-scale hatcheries have managed to generate significant incomes for the operators and numbers of fingerlings for other farmers, however, another problem has diluted their impact: deterioration of the genetic quality of cultured populations. This phenomenon is well documented in Asia, where the problem is proportional to that continent's much larger aquaculture industry.

Over 80% of the fingerlings delivered to African fish farmers come from small facilities like this sharptooth catfish hatchery in Batié, Cameroon. Its indoor hatching tanks are supplemented with seven small nursery and holding ponds – too little infrastructure to maintain sufficient broodstock to avoid inbreeding.

Catfish, Tilapia Limitations

The species most commonly produced by small-scale African hatcheries are the sharptooth catfish, *Clarias gariepinus*, and Nile tilapia, *Oreochromis niloticus*. Each presents hatchery operators with opportunities to mismanage broodstock.

For the highly fecund catfish, there is always the temptation to use the fewest number of broodfish possible to get a certain number of eggs. In addition, male catfish are usually sacrificed, and so are used to fertilize as many females as possible.

From these offspring of minimal numbers of parents will be selected the next generation of brooders. After several generations of such mating, inbreeding can reach levels sufficient to lower growth, fecundity, and fitness, and generate deformities.

Tilapia present a somewhat different challenge, but the outcome is the same. The typical practice at harvest among small-scale farmers is to sell or eat all fish of a certain minimum size, leaving smaller animals to be sold as fingerlings to other farmers or continue growing in the pond.

Only a part of these small fish are actually fingerlings. Many are small, sexually mature adults. Such selection for smaller adults, which amounts to inadvertent selection for slow growth and/or early sexual maturation, can lead to declines of up to 20% in growth rate within six generations in less than three years.

Ineffective Fingerling Production

Small-scale fingerling production in Africa is typically based in earthen ponds of 50-500 m^2, with or without some kind of hatchery building. Into these ponds are stocked various numbers and sex ratios of male and female tilapia of mixed sizes and genetic background.

Often the numbers of broodfish used are insufficient to maintain adequate genetic variability in the populations. Also, as male tilapia are highly territorial and competitive for mates, a relatively small percentage of males (the most aggressive, not necessarily the fastest-growing) dominate the fertilization of the females.

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Without some method of ensuring that most males are represented, the effective breeding number will be less than anticipated, and the population can become inbred, reducing growth and viability while increasing phenotypic variation.

Genetic Drift

Genetic drift, especially the founder effect, is another mechanism that can lead to loss of genetic diversity and the potential for inbreeding.

Larger farms are also not immune to the problems of deteriorating genetic quality.

Small founder populations are common in African aquaculture and, indeed, aquaculture in general. Exotic broodfish are expensive, difficult to acquire, and often illegal, so individuals often resort to minimal numbers. This builds low genetic diversity into production systems from the outset.

Declines in growth performance are often associated with such loss of genetic diversity. Typically, genetic variability on small-scale African hatcheries is 40-70% less than wild populations. These levels of loss are associated with growth rate declines on the order of 12-40% compared to wild stocks. See Table 1 for reported effects of poor genetic management.

Even with the relatively low fish production in Africa, a 20% decline in growth rate represents lost production on the order of 80,000 mt, with associated annual profits of U.S. $200 million lost to African fish farmers.

In addition, response to selective breeding can be reduced by up to a third by even moderate reduction of genetic variation. Heritability for growth in tilapia is naturally low to moderate, averaging less than 20%. It can easily be swamped by low effective breeding numbers. As demonstrated by a number of researchers, if the genotypes of few individuals are represented, mass selection has minimal effect on population growth rates.

Genetic Diversity

To prevent significant loss of genetic diversity, breeding numbers should be in the range of 100-150. Collecting, maintaining, and managing these numbers of broodstock is costly and complicated, precluding the vast majority of small- and even medium-scale operators. Larger farms are also not immune to the problems of deteriorating genetic quality.

Largely out of ignorance, rather than lack of capital, larger-scale fish farms have both inbreeding and outcrossing problems. Not only are most large hatcheries based on the same types of open pond-spawning systems used by small-scale hatcheries, but they also tend to import stocks and species from other farms and countries.

The Baobab Fish Farm Kenya, for example, grows a tilapia hybrid between *O. niloticus*, *O. spilurus*, and *O. mossambicus*. At Kafue Fish Farm in Zambia, which maintains stocks of *O. niloticus*, *O. andersonii*, *O. aureus*, wild *O. mortermeri* and *O. macrochir* come in from the Kafue River. All of these easily cross with each other and perform less well than the original *O. andersonii* stock. Similarly, a decline in growth rate of approximately 20% over three generations was observed by Micha et al. (1996), who studied the introgression of *O. macrochir* genes into a captive line of *O. niloticus* in Rwanda.

Proper Management

While difficult, proper management of captive tilapia genetic resources is not impossible. In those few cases where the genetic diversity of hatchery stocks has been systematically managed through the use of large effective breeding numbers or controlled outcrossing, growth rates equal or exceed those of natural populations. In addition, properly conducted selective breeding can lead to increases in growth rates of 16-70%.

Cited references are available from the author.

Table 1. Documented consequences of poor genetic management at small-scale hatcheries.

Reported Problems	Author(s)
Introgression *O. macrochir* into *O. niloticus* reduced growth	Micha et al. (1996)
Backcrossing generations of red hybrids lowered reproduction	Behrends
Well-managed stock 12% better than small hatcheries	Morissens et al. (1996)
Genetic variability down 50% in small hatchery stocks	Morissens et al. (1996)
Wild fish: 43% more genetic variability than hatchery stocks	Pouyard, Agnese (1996)
50% loss of genetic variability in small hatchery stocks	Agustin et al. (1997)
Wild populations better than African hatchery stocks	Eknath et al. (1993)
70% loss of genetic variability among hatchery stocks	Ambali et al. (1999)
50% less growth in hatchery versus Lake Victoria stock	Gregory