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Hybridization Between Oreochromis Species in Pond Culture: A Comparative Analysis

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Abstract

In freshwater and aquaculture contexts, hybridization between the Oreochromis species has recently increased in frequency. The purpose of this study was to assess the development of the gonadal/gametes in crossings between hybrids of *Oreochromis niloticus* and *Oreochromis andersonii* crossed (X) with hybrids of *Oreochromis niloticus* and *Oreochromis macrochir*. Nine males and eighteen female brooders, weighing an average of 180±0.32g, were first conditioned by keeping the males and females apart for a month. They were then fed a commercial diet at a body weight of 5%. In a completely randomized setup, the sexes were paired in a 1 x 2 m hapa at a 1:1 sex ratio and the process was repeated three times. The results indicate that the crosses between the hybrids did not breed after mixing the sexes for a period of six weeks. When subjected to laboratory analysis, three males out of nine had partial gonadal development, whilst six males had no gamete development and a single male developed full gonads. Female brood stock did not develop any gonads. The study demonstrates that the development of gametes in Oreochromis hybrids is unpredictable. It is therefore imperative to regularly replace brood stock in aquacultural facilities. While fish hybrids offer numerous benefits for aquaculture, it is crucial to carefully manage their introduction and breeding to mitigate potential ecological impacts such as invasiveness, genetic pollution, ecosystem changes and nutrient cycling, i.e., changes in fish populations can influence nutrient cycling within aquatic systems, affecting everything from water quality to habitat structure. Regulations and best practices should be implemented to ensure the sustainability of both aquaculture and natural ecosystems.

Keywords: Brood stock; Gametes; Genetics; Hybridization; *Oreochromis* species

Introduction

The need for high quality protein, especially from aquatic sources, has been rising substantially as a result of the increase in world population growth. To satisfy this need, increased aquaculture production is obviously required. Given the current state of overfishing, habitat loss, and population growth around the world, an increase in catches of fish is not expected under the current circumstances (Dunham *et al*., 2001). Development of better fish breeds that can contribute to increased fish production, while ensuring protection of biodiversity and the environment, is seen as one of the key solutions to meet future food demands of the growing world population (Gupta and Acosta, 2001a and 2001b). The advent of induced spawning techniques, such as hypophysation through use of pituitary gland extract to induce ovulation, synthetic hormones, *in vitro* fertilization technologies, and increased knowledge of reproductive biology, has enabled aquaculturists to induce breeding and domesticate many fish species for aquaculture. As domestication of fish species increases, the possibility of increasing fish production through appropriate genetic improvement methods also increases. Hybridization is considered as one of the simple, inexpensive, and potential tools of such enhancement programs in fishes; it is a useful method for combining the desirable traits of selected species. The mating of two different species is a process called hybridization, with the offspring known as hybrids. Hybrids can have some characteristics of both parental species. A hybrid with selected or favored characteristics of each parent is one of the goals of animal husbandry. When a hybrid has characteristics superior to both parents, it is said to have hybrid vigor or positive heterosis, which, of course, is the ultimate breeding goal. Hybridization occurs widely in fishes under natural conditions (Hubbs, 1955; Schwartz, 1981), and is observed in fish more commonly than in other vertebrate animal groups (Campton, 1987; Allendorf and Waples 1996). Several factors have been suggested as contributing to the high incidence of natural hybridization among closely related fish species, including external fertilization, weak behavioral isolating mechanisms, unequal abundance of the two parental species, competition for limited spawning habitat, and decreasing habitat complexity (Hubbs, 1955; Clampton , 1987).

Hybridization is the crossing of individuals of two populations that differ in one or more of the basic hereditary features. In nature there are reproduction isolation mechanisms that are blocking interspecies hybridization of animals. In fish, more often than in other vertebrates, interbreeding occurs. This is due to external fertilization and the specificity of the living environment. Under breeding conditions hybridization of fish, including salmonids, is easy to implement and under natural conditions in inter-specific hybrids such as salmon and trout appear to relatively rare, due to the presence of insulating mechanisms, mostly related to the separation of spawning sites. One of the main factors causing hybridization is, as a result of anthropogenic activities, disruption of the normal water conditions causing fluctuation of water level in rivers and reduction area of spawning sites. Roberts (2009) study highlights the under emphasized importance of estuaries as sites of hybridization and suggests that hybridization is driven both by opportunity for contact and human activity. Hybridization is a process that has a significant role in the process of evolution and the creation of new species. Hybridization is often used in biotechnology, in order to obtain specimens of advantageous (in terms of aquaculture) features. Thanks to hybridization populations are obtained with higher tolerance to cold, salinity, ammonia and better growth rates and greater resistance to disease.

Inter-specific hybrids are usually formed by mating two different species in the same genus. They are produced to increase growth rate, improve production performance, transfer desirable traits, reduce unwanted reproduction, combine other valuable traits such as good flesh quality, disease resistance and increase environmental tolerances, better feed conversion, and increase harvesting rate in culture systems. Hybrids play a significant role in helping to increase aquaculture production of several species of freshwater and marine fishes, for example, hybrid catfish in Thailand, hybrid striped bass in the USA, hybrid tilapia in Israel, and hybrid characids in Venezuela.

The potential for increasing prevalence of hybridization, particularly resulting from human activities, is high. Hubbs (1955) stated “It is evident that hybridization is conditioned by environmental factors”, mainly attributed to human disturbance. Anderson (1948) describes “hybridization of habitat” by human induced disturbance causing formerly reproductively isolated taxa to come into contact and mate. Habitat modification will likely continue to be an important contributing factor to the incidence of hybridization by facilitating geographic range expansion, creating dispersal corridors that allow movement of one species into the range of another, or by reducing available spawning habitat availability and thus constraining reproductive activities of different species into smaller areas (Rhymer and Simberloff, 1997).

Materials and Methods

Pure brood stock fish (180g ± 0.32) were collected from the breeding ponds within the National Aquaculture Research and Development Centre, while the cross hybrids were collected from a farmer within Kitwe district, Zambia. The brooders of each species were conditioned by sex separation for a month, then later brought together to breed at a sex ratio of 1 male : 1 female. All the fishes were sex separated for a month for the seek of synchronizing the breeding.

The research was then arranged in a completely randomized design where the breeding hapas were set in the same pond and subjected to the same water quality conditions.

Study Results

The crosses between the hybrids did not breed in the period of six weeks. The hybrids were then subjected to a laboratory analysis to determine the gonadal development. Three males out of ten had their gonads partially developed, whilst six males had their gametes not developed and only one male had a fully developed gonad. In the case of females, none of the ten had their gonads developed.

Figure: 01 Male hybrid with fully grown gametes

Figure: 02 Female hybrid with no distinct gametes

The results points to hybrids fecundity rate reduces with generation and therefore, sterility sets in, in subsequent generations.

Effects of hybridization

The harmful effects of hybridization, with or without introgression, have led to the extinction of many populations and species in many plant and animal taxa (Rhymer and Simberloff, 1996). Hybridization is especially problematic for rare species that come into contact with other species that are more abundant. Rhymer and Simberloff concluded that the severity of this problem has been underestimated by conservation biologists. *Oreochromis* species hybridize often, according to available evidence (Schwanck, 1995; Agnese *et al*., 1998; Deines *et al*., 2014). In South Africa, hybridization of *O. niloticus* with the native *O. mossambicus* has been recorded (Gregg *et al*., 1998; Moralee *et al*., 2000; D'Amato *et al*., 2007; Firmat *et al*., 2013); and in Lake Victoria (Welcomme, 1966; Mwanja & Kaufman, 1995; Angienda *et al*., 2010). According to a study by Deine *et al*., (2014), non-native Nile tilapia have proliferated throughout the Kafue River fisheries area in Zambia since they escaped in the 1980s and have mated with local *O. andersonii* and *O. macrochir*. Since that time, the chance for substantial hybridization and introgression between the native *Oreochromis* species and the escaping non-native *O. niloticus* species has existed. The increasing pace of the three interacting human activities that contribute most to increased rates of hybridization (introductions of plants and animals, fragmentation, and habitat modification) suggests that this problem will become even more serious. Over the past few years, Zambia has witnessed an increase in floating cage technology, particularly in the man-made Lake Kariba, where *O. niloticus* is the fish of preference for most cage farmers and escapees are inevitable (McCrary *et al*., 2001). There is no question that *O. niloticus*, which is spread through aquaculture, has the potential to compromise the genetic diversity of local fish species whenever and wherever they interact (Lind *et al*., 2012).

Amarasinghe, U.S., & Silva, S.S. (1996) estimated fecundity for 20cm fish, using fecundity-total length relationships for various populations, indicated that there was a decline in fecundity in hybrid forms, and further hypothesized that the long-term effect of cross hybridization between the two cichlids might lead to a decline in fish yields in perennial reservoirs of Sri Lanka. Blackwell *et al*. (2021) observed that Invasive freshwater fish systems are known to readily hybridize with indigenous congeneric species which leads to loss of unique and irreplaceable genetic resources as was seen in populations of *Oreochromis korogwe* from southern Tanzania being threatened by hybridization with the larger invasive *Oreochromis niloticus*.

The risk of introducing exotics, whether improved breeds are imported or bred from local hatcheries that develop their own local strains, environmental risks and that of livelihoods of local people are unavoidable. In Nairobi, Kenya, a declaration was made that looks at prior to introducing or developing of improved lines of tilapia for aquaculture, which recommended that a careful cost and benefit analysis including risk assessment should be thoroughly undertaken to address issues on Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species for Aquaculture in Africa within the prevailing ecological and socio-economic contexts should be conducted. Despite the fact that the development and use of improved strains has a high return on investment and increases growth rates and profits (Ponzoni *et al*., 2007), there are other important factors to take into account. These include; The existence of isolated or partially isolated populations that may have special adaptations for inter alia unusual environmental conditions or disease resistance; the potential presence of alien diseases and/or parasites in the fish to be translocated; The interconnections of water bodies; fish introduced into one water body often find their way into the other water body, who is the final economic beneficiary of this imported fish.

Negative Impact on Ecological Balance

Invasive Species Risk: If hybrid fish escape into natural water bodies, they have the potential to disrupt local ecosystems by out competing native species for resources, potentially leading to declines in biodiversity (DeBoer *et al*. 2014).

***Genetic Pollution**:* Interbreeding between hybrids and wild populations can lead to genetic changes in native species, which may affect their adaptability and survival (Allendorf & Luikart, 2007).

Ecosystem Changes: The introduction of hybrids may alter local food webs and ecosystem dynamics, potentially causing shifts in species composition and abundance (McCauley & Laurance, 2006).

Nutrient Cycling: Changes in fish populations can influence nutrient cycling within aquatic systems, affecting everything from water quality to habitat structure (FAO, 2013). Deines *et al*. (2014) suggested that managers should carefully account for these risks when considering further exotic introductions to regions where non-native tilapia have not yet become established .

In Zambia, the native tilapia population is seriously threatened by hybridization. According to several studies (Williamson, 1996; Cox, 1997; Vicente & Fonseca-Alves, 2013), hybridization may have a negative effect on fish biodiversity by homogenizing the gene pool, loss of private alleles, loss of fitness, disrupting the food chain, and causing local extinctions. Deines *et al*. (2014) observed that the state of tilapia biodiversity in the Kafue River suggests that non-native tilapia introduction may have negative impacts on the genetic resources available for aquaculture and fisheries and hence managers should carefully account for these risks when considering further exotic introductions to regions where non-native tilapia have not yet become established.

Conclusion

Even while hybrids grow much more faster than their pure parent, the study has proven that they have fewer to no chances of reproducing within themselves and that they should only be grown for consumption. Therefore, this study advises farmers not to consider selecting brood stock from such batches from generations of hybridization. While fish hybrids offer numerous benefits for aquaculture, it is crucial to carefully manage their introduction and breeding to mitigate potential ecological impacts. Regulations and best practices should be implemented to ensure the sustainability of both aquaculture and natural ecosystems. Responsible management and ongoing research are crucial to maximizing benefits while minimizing negative environmental impacts.

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