

Selective Breeding Programs in Aquaculture

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ABSTRACT

Aquatic environment is highly dynamic in nature and the aquatic organisms inhabiting in it have to withstand a wide range of variation. Hence selection of species with useful traits underpins in improving the genetic quality for enhancing domestication and production yield. Generally, selection aims for increasing yield, better survival rate, improved growth rate, resistance to biotic and abiotic stresses and for improving product quality. Genetically enhanced stocks account for less than 20% of global aquaculture production. This shows that non-genetically enhanced fish still account for the majority of aquaculture production. Insufficient information on the reproductive cycles of many cultivated species is a contributing factor to this scenario. Understanding the reproductive biology and behavior of these species is essential for successful genetic enhancement efforts. Many aquaculture organizations still use wild species for breeding purposes. Using wild-caught individuals can hamper species domestication and introduce genetic diversity that contradicts breeding goals. To achieve successful genetic improvement, researchers, extensionists, and fish farmers must grasp the genetic principles that influence desired qualities. This knowledge gap might hinder the creation and execution of successful breeding programs.

INTRODUCTION

India is the most populous country estimated to be around 1.44 billion, surpassing China in 2023. To feed such a

huge population is a matter of concern. Fish being the cheapest source of protein resolved the problem. From a fish farmer point of view,

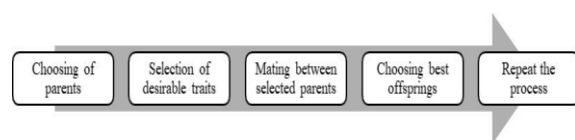
there are 2 ways in increasing the fish production to meet the ever-increasing population: firstly, increasing the size of the farm and secondly, increasing the fish yield in terms of weight. It is practically impossible to always increase the fish farm size. Hence, we opt for second option which can be through environmental manipulation or by growing genetically modified fish. And in both the methods the yields have increased dramatically.

There are several breeding programs in India of which Selective breeding is the traditional approach towards increasing the fish yield.

What is selective breeding?

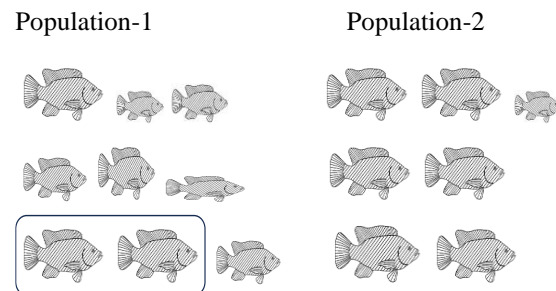
Selective breeding is a genetic improvement strategy designed to enhance the breeding value of a population by systematically selecting and mating individuals exhibiting superior phenotypic traits, such as higher growth rates, increased body mass, or specific coloration patterns (Ayyappan *et al.*, 2011). The objective is to ensure that these heritable traits are transmitted to the progeny, resulting in successive generations with improved performance metrics—such as accelerated growth, enhanced feed conversion efficiency, or elevated marketability due to favorable aesthetic attributes.

Steps involved in selective breeding.



The fish from the given population is chosen exhibiting the desired traits that are considered genetically superior. Mating is done by selecting the fish in pair for breeding either by natural mating or artificial insemination. The offsprings showing desirable traits are evaluated and the best offsprings are chosen with required characteristics to breed in further

generation (Kincaid *et al.*, 1977; Hallerman *et al.*, 2021). The entire process is repeated for multiple generations to accumulate the desired genetic gain in the population.



Parents selected

Examples of selective breeding programs of the world

1. GIFT Tilapia

The WorldFish Center's GIFT (Genetically Improved Farmed Tilapia) initiative produced a tilapia strain with faster growth, greater survival rates, and improved disease resistance (Eknath *et al.*, 1993; Hallerman *et al.*, 2021). The WorldFish Center has also been successfully used with Nile tilapia and other tilapia species in Egypt, Ghana, and Malawi, as well as with other fish species such as carp.

Improved traits:

Growth rate, body form, and disease resistance, has resulted in enhanced tilapia strains for aquaculture.

2. Salmon

In Chile, selective breeding of coho salmon led to a 13–15-day shorter spawning season after four generations. Atlantic salmon have been selectively bred for improved growth, survival, and disease resistance, making them a valuable species in the aquaculture business (Emboday and Hayford, 1925; Donaldson and Olson, 1957). Selective breeding has produced all-female salmon populations, which can benefit aquaculture due to their greater and faster growth rates compared to males.

Improved traits:

Early spawning, improved growth, disease resistance and sex reversal.

3. Jayanti rohu

The Indian Council of Agricultural Research-Central Institute of Freshwater Aquaculture (ICAR-CIFA) and the Institute for Aquaculture Research (AKVAFORSK), Norway, began selective breeding of rohu in India in 1992.

Improve traits:

Genetic improvement of Jayanti Rohu with 17% higher growth efficiency per generation has been reported (Mahapatha *et al.*, 2016). Completed 13 generations of selective breeding. It shows additional trait of disease resistant towards *Aeromonas hydrophila*.

4. GI Scampi

The ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA) has made significant advancements in freshwater prawn research, leading to the creation of CIFA-GI SCAMPI®—a genetically enhanced strain of *Macrobrachium rosenbergii*. Beginning in 2007, ICAR-CIFA partnered with WorldFish, Malaysia, to launch a structured selective breeding program aimed at producing a faster-growing scampi variety. This improved strain has demonstrated a cumulative growth gain of 7.2% over 16 generations.

Improved traits:

Growth rate and disease resistance.

5. Amrit Catla

CIFA has launched a genetically modified Catla called AMRIT CATLA, a Selective breeding program which began from 2010.

Improved traits:

A 35% cumulative gain by 3rd generation for improved aquaculture productivity. Better feed efficiency, higher survival rates and better disease resistance.

Outcomes of selective breeding programmes:-

In 1925, Embury and Hayford selected surviving Brook Trout (*Salvelinus fontinalis*) from an endemic furunculosis population. The survival rate increased from 2% to 69% after three generations of selection.

In 1971, AKVAFORSK began breeding experiments for Atlantic Salmon and Rainbow Trout in Norway, which eventually became a national breeding program. Selection criteria were growing rate, low incidence of early maturation, and disease resistance. Flesh quality, color, and fat proportion. By 1985, salmon and trout had shown 13% and 14.4% genetic increases, respectively.

Selective breeding improved the growth rate of GIFT Nile Tilapia significantly. The program improved growth rates from 77% to 123%, surpassing crossbreeding findings. The program We were able to accomplish an amazing 11 percent genetic increase every generation in GIFT tilapia. This pace of genetic improvement stands out when compared to similar breeding efforts in other fish species.

Application of selective breeding programs

- As a tool: Selective breeding involves selecting species with desirable features as parents for future generations, increasing the incidence of those traits over time. This approach aims to improve the Genetic composition of aquatic organisms for aquaculture applications.
- Including genetic considerations and well-designed selective breeding programs in

aquaculture can improve success rates. This requires careful planning. Implementation of breeding strategies to attain desired characteristics.

- Selective breeding involves human intervention in adaptation, replacing natural selection with controlled breeding methods. This modification of the natural evolutionary process can result in both. Aquaculture can have both beneficial and harmful results depending on the qualities used.
- Selective breeding programs inside the aquaculture business may be more efficient and aligned with commercial goals, notwithstanding academic institutions' contributions to genetic data collection and research.
- Selective breeding aims to assist the aquaculture business adapt to changing market needs by developing superior stocks with desirable features.

Pros and Cons of selective breeding in aquaculture: -

Pros

1. **Increased production:** Selective breeding can result in quicker growth rates, larger yields, and increased overall productivity, potentially lowering costs per unit of production.
2. **Improved disease resistance:** Selective breeding can increase disease resistance, lower mortality, and improve the general health of farmed fish.
3. **Reduced feed costs:** Breeding for features such as increased feed efficiency can greatly reduce the cost of aquaculture operations.
4. **Market demand:** Selective breeding allows fish to be tailored to certain market

demands such as size, color, and nutritional content.

5. **Adaptability:** Breeding for features that make fish more adaptable to specific situations can boost their resilience and reduce stress.

Cons

1. **Inbreeding depression:** Close inbreeding in selective breeding programs can result in a loss of genetic variety and inbreeding depression, which is a fall in fitness caused by the accumulation of detrimental recessive alleles.
2. **Reducing genetic diversity:** Focusing on a few desirable features might reduce the genetic pool, making the population more susceptible to illnesses and environmental changes.
3. **Undesirable consequences:** Selective breeding can result in unanticipated undesirable features, such as reduced reproductive ability or physical abnormalities.
4. **Ethical concern:** Selective breeding can raise ethical concerns about animal welfare, particularly if it results in physical malformations or impairs the animals' capacity to live a normal life.

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