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Popular Article

Sex Determination in Aquaculture and its Applications

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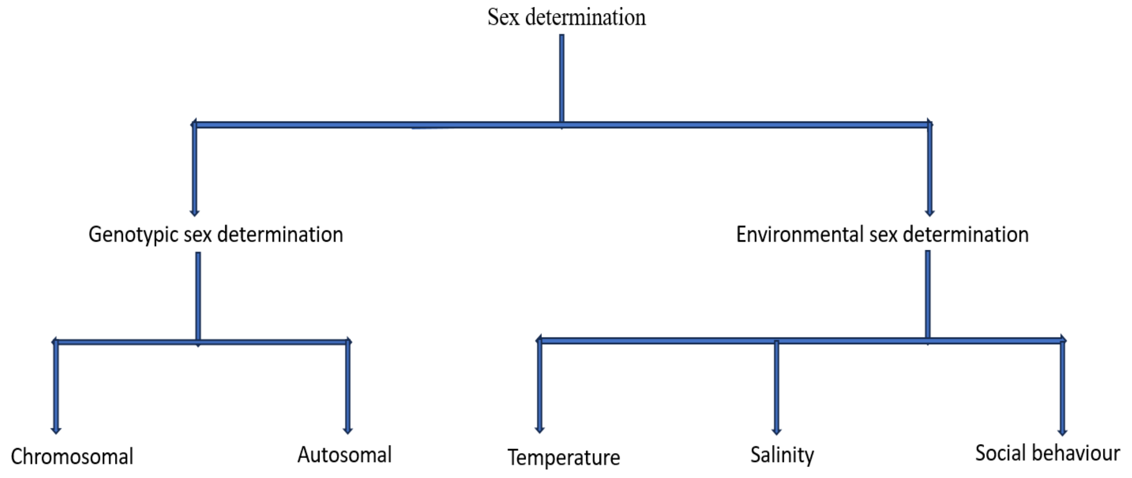
Sex determination is an important aspect of aquaculture, impacting production significantly. By controlling the sex of aquatic organisms, aquaculturists can maximize productivity, as different sexes often exhibit varying growth rates and market values. This control enhances efficiency, reduces production time, and increases overall yields. Furthermore, it plays a crucial role in selective breeding programs, improving genetic traits and sustainability. Sex determination aids in disease management, allowing for more effective control strategies by segregating sexes. It also reduces environmental impact by optimizing resource utilization and minimizes unwanted costs, making aquaculture more economically sustainable. In essence, sex determination in aquaculture is essential for productivity, genetic improvement, disease control, environmental responsibility, and economic success. There are various types of sex determination systems.

Types of sex determination



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Genotypic sex determination

Genetic Factors

Genetics plays a crucial role in determining the sex of fish in aquaculture. The sex of many fish species is determined by their genetic makeup, specifically the combination of sex chromosomes. For example, in many species, females have two identical sex chromosomes (homogametic, denoted as XX), while males have two different sex chromosomes (heterogametic, denoted as XY). This genetic sex-determination system is similar to that of humans, where females have two X chromosomes (XX) and males have one X and one Y chromosome (XY).

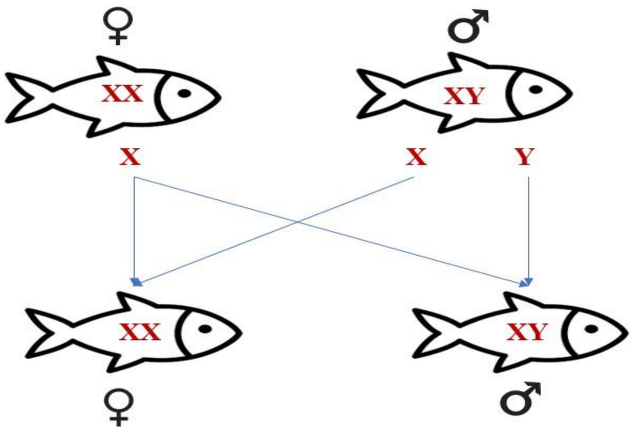
Types of Genotypic Sex Determination

Genotypic sex determination is a system where an organism's sex is determined by its genetic makeup, specifically the combination of sex chromosomes.

1. Chromosomal sex determination

Chromosomal sex determination refers to the process by which an organism's sex is determined by the presence or absence of specific sex chromosomes. There are several types of chromosomal sex determination systems.

1) XX/XY System



In this system, females typically have two identical X chromosomes (XX), and males have one X and one Y chromosome (XY). In this male is heterogametic. Y chromosome in the male determines the sex. It is commonly found in Channel catfish (Davis *et al*., 1990), Rainbow trout (Thorgaard, 1997), Common carp (Nagy *et al*., 1981), Silver carp (Mirza and Shelton, 1988), and Grass carp (Stanley, 1976).

2) ZZ/ZW System

In this system, females have a pair of different sex chromosomes (ZW), while males have two of the same sex chromosomes (ZZ). In this female are heterogametic. W in the female determines the sex. This system is found in *Tilapia aurea* (Guerrero, 1975), Japanese

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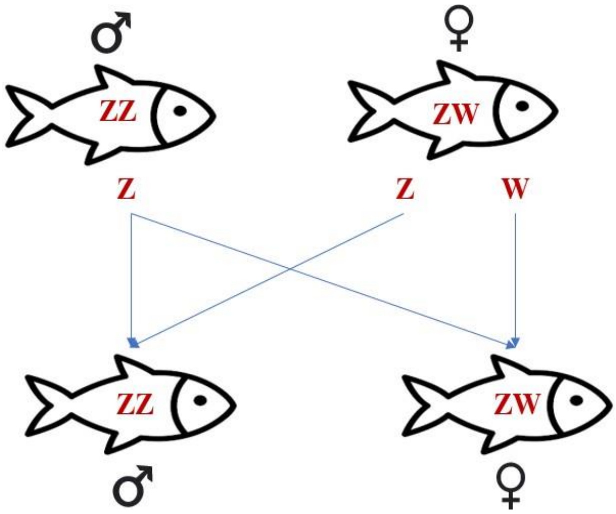
eel (Park and Kang, 1979).



3) XO System

In the X0 system, females have two X chromosomes (XX), while males have only one X chromosome (X0). Here also male determines sex. If the X chromosome receives from male to offspring, then it is female if not male. This system is observed in Dollar hatchet fish (Chen, T.R., 1969).

4) ZO System

In the ZO System, a female has ZO and a male ZZ. Here female determines the sex. If the Z chromosome receives from male to offspring, then it is male if not female.

Example: Dwarf gourami (Rishi, 1976).

Multiple sex determination system

5) X_1X_2Y System

In this Females have $X_1X_1X_2X_2$ while males have X_1X_2Y. Males are heterogametic. If X_1X_2 are present then female or if Y then male.

Example: Freshwater gobi (Pezold, 1984).

6) ZW_1W_2 System

Males have ZZ and females ZW_1W_2. females are heterogametic. Females determine the sex. Those who receive W_1W_2 are Females only Z are males.

Example: Virolito (Filho *et al.*, 1980).

7) Multiple Y system

Males XY_1Y_2 and females XX. The male determines the sex. If Y_1Y_2 them male if XX them female.

Example: *Hoplias* species (Bertolo *et al.*, 1983).

8) WXY System

The X chromosome is modified as W, this will block the male-determining ability of the Y chromosome. XX and XY are males, and XX, WX, and WY are Females. Both are either homogametic or heterogametic.

For example: Platyfish (Gordon, 1946).

9) Autosomal sex determination

The autosomes determine the sex of the offspring. Number of genes present on the autosomes determines the sex of the offspring.

Example: Swordtail and Blue poecilia (Koisswig, 1964).

2. Environmental Sex Determination

Environmental sex determination (ESD) is a captivating phenomenon, where external factors, rather than fixed genetic factors, determine the sex of aquatic organisms. It is mostly seen in fish and reptiles and it is a process by which various environmental factors play a key role in deciding the sex of an individual. Sex change is a purely ontogenetic event in some species but in others is triggered by environmental stimuli (Godwin et al., 2003).

Temperature

Temperature will influence the sex of the offspring. For example, some species of sea turtles exhibit temperature-dependent sex determination, where the incubation temperature of their eggs determines the sex of the hatchlings. Warmer temperatures tend to produce females, while cooler temperatures lead to male offspring.

Social behaviour

Two species of coral reef fish were found to exhibit socially mediated functional sex change. Sex change is observed in two patterns. Protandry, or "first male," is the term used to describe male-to-female sex transition, while protogyny, or "first female," refers to female-to-male sex change.

Salinity

Salinity-induced sex determination in fish links high salinity (hyperosmotic conditions) to male development and low salinity (hypoosmotic conditions) to female development, making it a remarkable example of environmental influence on sex determination in certain aquatic species. This phenomenon is observed in fish inhabiting estuarine or brackish water environments, offering aquaculturists a means to manage sex ratios in response to changing environmental conditions.

Example: Mozambique tilapia (*Oreochromis mossambicus*)

Applications of the Sex determination

Sex determination in aquaculture has several important applications.

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Selective Breeding

Sex determination methods help aquaculturists select and breed individuals with desirable traits, such as rapid growth, disease resistance, or specific colours, leading to the development of improved and commercially valuable strains.

Optimized Stocking Density

By controlling the sex ratio in a population, aquaculturists can manage stocking density to reduce competition for resources and improve the overall growth and health of the cultured species.

Efficient Resource Allocation

Accurate sex determination enables better resource allocation, reducing the cost of feed, space, and other inputs. This, in turn, enhances the economic sustainability of aquaculture operations.

Enhanced Disease Management

Different sexes may exhibit varying susceptibility to diseases. Aquaculturists can use sex determination to segregate populations or implement sex-specific health strategies, reducing the impact of diseases on their stock.

Market Demand and Profitability

Sex determination techniques help meet market demand by producing more of the desired sex, increasing the overall profitability of aquaculture enterprises, especially in species where one sex is more valuable than the other.

Monosex culture

Sex determination techniques allow for the production of monosex populations, which can improve growth and production efficiency. Techniques such as hormonal sex reversal have been successfully applied in species like tilapia (Razzaque *et al*., 2020) and catfish (Brummett *et al*., 2001).

Preventing reproductive maturation

Sex determination helps prevent premature reproduction, which can affect growth and production efficiency. For example, in Nile tilapia, separating the sexes early in development can prevent unwanted reproduction (Baroiller *et al*., 2009).

Enhanced growth rates

Sex-selective breeding based on sex determination can improve growth rates. Studies have shown that in species like Nile tilapia, selecting for faster-growing sexes can lead to improved growth performance (Ponzoni *et al*., 2011).

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Reduced environmental impact

Controlling the sex composition of populations can reduce environmental impacts. For instance, in pond-based systems, preventing spawning events by separating sexes can reduce nutrient loadings and water quality issues (Beveridge *et al*., 1996)

Genetic improvement programs

Sex determination facilitates selective breeding programs for desirable traits. In Atlantic salmon, sex-specific genetic markers have been used to accelerate genetic improvement (Barson *et al*., 2015).

Risk management

Sex determination helps manage risks associated with reproductive behaviour. For example, in barramundi, controlling sex ratios can minimize aggression and cannibalism, improving production outcomes (Siti Azizah *et al*., 2021).

Conservation and stock enhancement

Sex determination is crucial for conservation efforts. In species like the Chinese sturgeon, sex identification techniques aid in maintaining genetic diversity and supporting stock enhancement programs (Liu *et al*., 2021)

Conclusion

Sex determination plays a pivotal role in various aspects of aquaculture management, offering a range of benefits including improved production efficiency, environmental sustainability, and genetic enhancement. By employing sex determination techniques, aquaculturists can implement monosex culture, prevent premature reproduction, enhance growth rates, mitigate environmental impacts, manage risks associated with reproductive behavior, and support conservation and stock enhancement efforts. These applications contribute to the optimization of aquaculture operations, ensuring sustainable production while addressing challenges related to reproduction, genetic diversity, and environmental stewardship. Continued research and innovation in sex determination technologies and their integration into aquaculture practices will further advance the industry's ability to meet growing global demand for seafood while minimizing environmental impacts and maximizing economic returns.

The Future of Sex Determination in Aquaculture

As aquaculture continues to grow, innovative techniques and technologies in sex determination will emerge. The future holds promise of refined genetic selection, environmentally conscious practices, and the harmonious coexistence of nature and nurture, ensuring a thriving, sustainable, and productive aquaculture industry.

References

Baroiller, J. F., D'Cotta, H., & Saillant, E. (2009). Environmental effects on fish sex
1019 determination and differentiation. Sexual Development, 3(2-3), 118-135.

Barson, N. J., Aykanat, T., Hindar, K., Baranski, M., Bolstad, G. H., Fiske, P., ... & Glover, K. A. (2015). Sex-dependent dominance at a single locus maintains variation in age at maturity in salmon. Nature, 528(7582), 405-408.

Beveridge, M. C. M., Phillips, M. J., & Macintosh, D. J. (1996). Aquaculture and the environment: The supply of and demand for environmental goods and services by Asian aquaculture and the implications of growth. World Aquaculture, 27(2), 7-14.

Brummett, R. E., & Ponzoni, R. W. (2001). Gender in fish: Sex determination mechanisms and applications in aquaculture. Reviews in Fish Biology and Fisheries, 10(4), 463-482.

Devlin, R.H. and Nagahama, Y., 2002. Sex determination and sex differentiation in fish: an overview of genetic, physiological, and environmental influences. *Aquaculture*, *208*(3-4), pp.191-364.

Godwin, J., Luckenbach, J.A. and Borski, R.J., 2003. Ecology meets endocrinology: environmental sex determination in fishes. *Evolution & development*, *5*(1), pp.40-49.

Liu, H., Wang, J., Gao, X., Fu, X., Zhang, S., Li, X., ... & Wang, Z. (2021). Optimizing polyploid induction to facilitate the Chinese sturgeon Acipenser sinensis conservation aquaculture. Conservation Physiology, 9(1), coab012.

Ponzoni, R. W., Nguyen, N. H., Khaw, H. L., & Hamzah, A. (2011). Genetic improvement of Nile tilapia (Oreochromis niloticus) with special reference to the work conducted by the WorldFish Center with the GIFT strain. Reviews in Aquaculture, 3(1), 27-41.

Razzaque, A., Alam, M. S., Hasan, M. R., & Khan, M. N. A. (2020). Sex control in tilapia: A review. Aquaculture Reports, 17, 100370.

Siti Azizah, M. N., George, S., & Basri, M. (2021). Aquaculture of barramundi (Lates calcarifer): Current status, challenges, and future perspectives. Reviews in Aquaculture, 13(1), 327-355.

Thomas, P.C., 2003. Breeding and seed production of fin fish and shell fish. Daya Books.