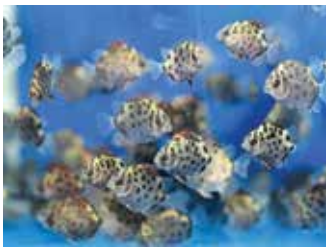
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Editor,
Fish Tech Digest



From the desk of Dean…

Dear esteemed Authors and Readers

It gives us immense pleasure to present this special issue of Fish Tech Digest, dedicated to the fisheries wealth, aquatic ecosystems, and coastal communities of Kanniyakumari District. Located at the southernmost tip of India, Kanniyakumari is blessed with diverse marine and inland aquatic resources that support livelihoods, biodiversity, and economic development.

This issue features insightful articles on the Ramsar wetlands of Vembannur and Suchindram–Theroor, the rich seaweed resources of Cape Comorin, and the vital role of Thengaipattinam Fishing Harbour in the marine fish export chain and coastal economy. Together, these contributions highlight the district's unique ecological and fisheries significance.

We are particularly pleased to showcase articles contributed by the faculty and students of St. Devasahayam Institute of Fisheries Science and Technology (DIFST), reflecting the institution's commitment to fisheries education, research, innovation, and sustainable development.

As the Blue Economy gains momentum, Kanniyakumari stands as a model where natural resources, traditional knowledge, scientific research, and community participation converge to create opportunities for sustainable growth. We hope this issue inspires readers to appreciate, conserve, and responsibly utilize these valuable aquatic resources for future generations.

I extend my heartiest congratulations to all the authors for their invaluable contributions. Your insights significantly enrich our collective academic knowledge and will undoubtedly inspire future research pathways. I trust that this issue of Fish Tech Digest will serve as a highly inspiring and practical resource for you all, as we continue to uphold our institutional benchmark for excellence in fisheries education, research, and community extension.

Best regards,
Prof. S. Felix
Chief Editor
Fish Tech Digest

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The Scientific Journey of Zebrafish

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Abstract:

Zebrafish (*Danio rerio*), has proven to be one of the most successful vertebrate animal models in the current era of biological and environmental sciences. In the last several decades, this tropical freshwater fish, which is about 3 – 5cm in length, has gradually moved from a specialized to a prominent research tool because of their high degree of genetic similarity to mammals, transparency of their embryos, shorter life span and lower maintenance costs. Zebrafishes are currently employed in scientific research endeavours to comprehend developmental biology, genetics, toxicology, pharmacology, neurobiology, diseases and environmental studies. This article will discuss the scientific history of zebrafish, pointing out their salient features, their applications in scientific inquiries and findings from experiments explaining the role of zebrafish in comprehending human biology and diseases.

Introduction

For any biological discovery, model organisms play a key role, such as fruit flies, mice, zebrafish, rats, rabbits and monkeys. Each model has provided basic mechanisms in understanding fundamental molecular and cellular processes. Among these models, zebrafish (*Danio rerio*) has been considered a powerful and versatile vertebrate model over the last few decades (Mukherjee et al., 2022). Introduced as a basic model for the research to study the developmental biology studies, the zebrafish has now become indispensable in different walks of research domains due to its unique biological characteristics.

Biological characteristics

The advantages of the zebrafish are its optical clarity during early development stages, its high reproducibility, and ease of genetic manipulation. The advantage that gives the zebrafish a distinct superiority over any other model system and makes it the best system available for researchers to make a discovery that could never be done before is that it has a high homology with human genes and physiology (Binesh, 2021). Currently, interest in zebrafish research lies in the intersection of basic science and translational as well as environmental health sciences.

Genetic and physiological similarities

A major contributor to the widespread use of zebrafish in studies and experiments is their close genetic identity with humans. Genome analysis has identified that there exists at least one ortholog present in zebrafish for 70% of the genes identified in humans, and for about 84% of genes that cause diseases in humans, zebrafish have similar genes. “This homology is more than the mere presence of genes.” Many of the signaling pathways and developmental processes are conserved in the zebrafish and

the human because genes necessary for cell cycle regulation, organogenesis and signaling lead to similar outcomes in the zebrafish and the mammalian counterparts, and hence predictions can be reliable in zebrafish experiments (Siddiqui *et al.*, 2025).

Optical transparency and rapid development

Zebrafish embryos are external, fast-developing, with prominent organs forming 24-48 hours after fertilization. One of the advantages of zebrafish embryos is their transparency, which enables researchers to visually observe, under a microscope, physiological events like the formation of heart tubes, development of nerve cells, or organ positioning. The observation of such processes of vertebrate embryos is unprecedented, as it does not involve procedures on live organisms. These benefits have helped facilitate large-scale genetic and pharmacologic screens. Genes and proteins can be easily manipulated in embryos by CRISPR/Cas9, morpholinos (MOs), transgenic reporters and developmental events can be quantitatively visualized by fluorescent proteins (Angom *et al.*, 2025).

Maintenance and fecundity

Unlike mammalian models, zebrafish can be easily raised and can be maintained in large quantities. A pair of healthy zebrafish can produce hundreds of embryos in every breeding, which allows for high throughput and adequate experiments, making it easy for zebrafish research across the world. Taken together, these aspects form an experimental model system, which is genetically tractable, experimentally tractable and scalable; this makes the applicability of zebrafish versatile (Angom et al., 2025).

Research Applications

Zebrafish were initially recognized as a model organism for the development of vertebrates. Their transparent embryos, as well as their well-characterized gene signaling pathways, make them ideal candidates for the study of cellular differentiation, migration and the formation of tissues and organs. Developmental processes of the heart, eye, brain, and neural crest have been shown in zebrafish to be essentially the same in the human organism. Fish and mammals have somewhat different body compositions. However, the majority of the developmental routes are identical (Tonelli et al., 2020).

Genetic similarities of zebrafish made it possible to insert mutations similar to those seen in human diseases. Various models of zebrafish have already been developed to study human conditions, including models of cancer, cardiovascular disease, muscular dystrophy and metabolic disorders. In neurodegenerative disorders, zebrafish have aided understanding of neurodegenerative disorders such as Alzheimer's. The neurochemical signals of zebrafish brains are functionally similar to those of human brains, hence used in research to induce some aspects of Alzheimer's pathology, thus translating to research efforts to treat these conditions. It also aids in understanding a variety of metabolic and epithelial disorders (Chia et al., 2022). Zebrafish models of human diseases include those relating to disorders in the liver, gastrointestinal tract and kidneys.

Zebrafish have been widely employed in toxicological studies of chemicals, environmental pollutants and pharmaceuticals. Zebrafish susceptibility to xenobiotics and the amenability of their toxicity mechanisms

make it possible to measure toxicity efficiency. Scientific studies on zebrafish revealed that various chemicals in the environment, such as pesticides, metals and pharmaceuticals, alter the expression of genes, physiology and development in zebrafish. It is impressive to acknowledge that zebrafish help in the identification of microRNA expression in the presence of toxicants at the molecular level to identify mechanisms of toxicity (Bambino and Chu, 2017). Zebrafish embryo tests have also demonstrated the difference in toxicity of comparable chemical compounds, proving that zebrafish tests are reliable in predicting toxicity output in mammals. The high reproductive rate and transparent embryos of zebrafish make these animals very useful for high-throughput drug screening. For example, simply by oral exposure of drugs researcher can study the developmental, behavioural, and physiological abnormalities. The zebrafish has been used as a model for high-throughput drug screening for cancer, cardiovascular, neurodevelopment and regeneration in retinal cells. The zebrafish model of drug discovery has filled a crucial gap between *in vitro* cell culture studies and mammalian studies, increasing the discovery of new drugs for human diseases.

Ethical advantages

One of the main scientific benefits of zebrafish is their use in animal research ethics. Zebrafish embryos are relatively less bound by regulations with respect to mammals; hence, their study during the early stages of their life cycle will not violate laws regarding animal welfare standards. Pragmatically speaking, the principal scientific benefit of the zebrafish model is the low startup investment or space needed for their utilization compared to rodent research infrastructure. Zebrafish research involves the accommodation of a huge population of fish within a smaller space (Strahle *et al.*, 2012).

Limitations and Future Directions

Despite these numerous benefits, zebrafish also pose several limitations. Zebrafish are devoid of some mammalian organs including lungs and a septate heart. Moreover, teleost whole genome duplication, which led to gene duplications, might result in reduced capability of deciphering gene functions. Despite the above challenges, advances in genetic methods (such as CRISPR technology), imaging and modeling are continually improving the use of the zebrafish. New research avenues emerging include microbiome studies, the use of zebrafish for regenerative medicine applications, environment studies and precision or personalized medicine. Zebrafish models are now also being combined with artificial intelligence to handle complex behavioural or physiological data (Tasnim et al., 2024).

Conclusion

The scientific path of the zebrafish, from being a curiosity within the aquarium tank to forming the basis of scientific research, is a proof of the wide-ranging impact of this model organism on the scientific community. Due to their gene similarity with human beings, the transparency of their developmental stages, the ability to easily manipulate them, and their applicability to various researches, the use of zebrafish has made major contributions to the understanding of vertebrates. Studies by peers in the scientific community have shown the ability of zebrafish to not only model human biological systems, but to possess some

advantages over more established models as well. In the upcoming years with emerging advianced technologies, zebrafish will play an important role in biomedical research by providing novel innovations for scientific need. To summarize, the little zebrafish has had and will continue to have great scientific relevance, paving the way for discoveries that will benefit humans, the environment, and their perception of life.

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