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THE FUTURE OF FISH FARMING: HOW AI, GENOMICS AND PRECISION AQUACULTURE ARE TRANSFORMING THE BLUE REVOLUTION

Email

Judith Betsy, C.

betsy@tnfu.ac.in

Institute of Fisheries Post Graduate Studies, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Vaniyanchavadi, Chennai, India

Fish is one of the world's most nutritious and sustainable sources of animal protein, supplying essential amino acids, omega-3 fatty acids, vitamins and minerals. As the global population is expected to approach 10 billion by 2050, the demand for safe and nutritious seafood will continue to increase. However, capture fisheries have reached their biological limits, making aquaculture the fastest-growing food production sector in the world. Today, aquaculture supplies more than half of the aquatic foods consumed globally, highlighting the crucial role of aquaculture in ensuring future food and nutritional security (FAO, 2024).

Aquaculture faces major challenges, including disease outbreaks, rising feed costs, declining water quality and climate change. Traditional farming practices, largely based on routine management and experience, are no longer sufficient to meet these challenges. A new era, Aquaculture 4.0 is therefore emerging, integrating Artificial Intelligence (AI), genomics and precision aquaculture to make fish farming smarter, more productive and environmentally sustainable (Joffre et al., 2022).

Artificial Intelligence: The Digital Brain of Fish Farming

Artificial Intelligence (AI) enables computers to analyse vast amounts of data, identify patterns and support management decisions. In aquaculture, AI is improving feeding, health management and water quality monitoring. Smart feeding systems equipped with cameras and computer vision estimate fish appetite and deliver feed only when required, reducing feed wastage and improving feed conversion efficiency. Since feed accounts for nearly 50–70% of production costs, even small improvements significantly increase farm profitability (Føre et al., 2018).

AI is also becoming an effective tool for disease surveillance. Machine-learning algorithms analyse fish behaviour and identify subtle changes in swimming activity or feeding response that often occur before visible disease symptoms appear. Early detection enables timely intervention, reducing mortality and limiting the use of antibiotics (Li et al., 2023).

Networks of sensors continuously monitor temperature, dissolved oxygen, pH and ammonia, while AI analyses these data and recommends immediate corrective actions. Such systems reduce production losses while conserving water and energy. Rather than replacing farmers, AI serves as a reliable digital assistant that supports faster and more informed decision-making (Kumar et al., 2023).

Genomics: Building Better Fish for Tomorrow

The reasons for fish growth, disease resistance and higher feed utilisation lie in their genes. Genomics, the study of an organism's complete genetic makeup, is transforming aquaculture by enabling scientists to develop superior fish and shrimp with improved productivity and resilience (Houston et al., 2020).

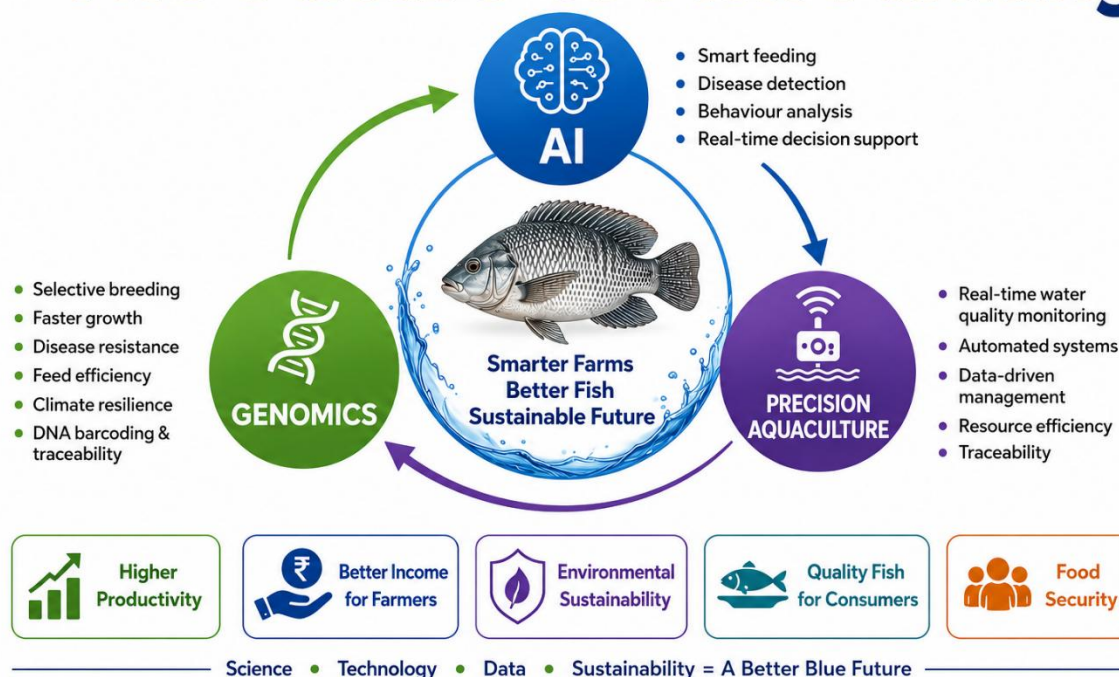
Genomics has already contributed to the development of faster-growing and disease-resistant strains of Atlantic salmon, Nile tilapia and Pacific white shrimp. Improved genetic stocks not only enhance production but also reduce dependence on antibiotics and other chemical treatments, contributing to more sustainable aquaculture (Gjedrem & Rye, 2018).

Beyond breeding, genomic tools such as DNA barcoding support accurate species identification, biodiversity conservation and traceability of seafood products. As sequencing technologies become increasingly affordable, genomics is expected to play a central role in developing climate-resilient strains of aquaculture species capable of meeting future food demands (Yue, 2023).

Precision Aquaculture: Farming with Data

Modern fish farming is increasingly shifting from experience-based management to data-driven decision-making. Precision aquaculture combines digital sensors, automation and cloud computing to monitor production continuously and respond to changing farm conditions in real time (Føre et al., 2018).

The Future of Fish Farming



Production records on growth, feed efficiency and survival help farmers improve planning, reduce waste and increase profitability. When integrated with AI and genomics, precision aquaculture provides a comprehensive management system capable of enhancing productivity while minimising environmental impacts (Joffre et al., 2022). Ultimately, precision aquaculture empowers farmers to make informed decisions based on scientific evidence rather than guesswork, paving the way for a more efficient and sustainable aquaculture industry.

India's Opportunity in the Digital Blue Revolution

India, the world's second-largest fish producer, relies on aquaculture for food security, livelihoods and export earnings. However, increasing disease outbreaks, rising production costs and climate-related challenges demand a shift from conventional farming to technology-driven aquaculture.

Increasing smartphone penetration and internet connectivity offers new opportunities for adopting AI and precision aquaculture even in small and medium-scale farms. Affordable sensors, automated feeders and mobile applications can help farmers monitor water quality, optimise feeding and receive real-time technical guidance. Similarly, genomic breeding programmes can accelerate the development of fast-growing, disease-resistant and climate-

resilient strains of commercially important species such as Indian major carps, tilapia and shrimp. By integrating research, digital technologies and effective extension services, India is well positioned to lead the next phase of the Blue Revolution.

Conclusion

The future of aquaculture lies in producing more fish with fewer resources while ensuring environmental sustainability. Artificial Intelligence, genomics and precision aquaculture are no longer futuristic concepts but practical tools that are already improving fish health, feed efficiency, farm management and profitability across the world. Together, these technologies enable farmers to make informed decisions based on real-time data rather than intuition.

Although challenges such as investment costs, technical expertise and infrastructure remain, rapid technological advances are making these innovations increasingly affordable and accessible. With continued research, capacity building and farmer-friendly technologies, Aquaculture 4.0 has the potential to transform fish farming into a smarter, more efficient and environmentally sustainable enterprise. The next Blue Revolution will therefore be driven not only by better farming practices but also by the intelligent application of science and technology.

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