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Smart Fish Farming: When Artificial Intelligence Starts Managing a Fish Pond

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Aquaculture is rapidly moving from conventional experience-based farming toward data-driven and automated production systems. Smart fish farming combines artificial intelligence (AI), Internet of Things (IoT) sensors, computer vision, machine learning, automated feeders, water-quality monitoring systems and predictive analytics to improve fish production. AI can continuously analyse information such as dissolved oxygen, temperature, pH, turbidity, fish behaviour, feeding response and biomass, helping farmers make faster and more accurate decisions. Modern systems can also predict changes in water quality, optimize feeding, identify abnormal fish behaviour and support early disease detection. Recent developments in AIoT, digital twins, robotics and intelligent decision-support systems are expanding the possibilities for precision aquaculture. However, successful adoption requires reliable data, affordable equipment, farmer training, connectivity and human supervision. Smart fish farming should therefore be viewed not as replacing farmers, but as providing farmers with better information and timely decision support. The integration of AI with sustainable management can improve feed efficiency, reduce environmental losses, enhance fish welfare and contribute to profitable and resilient aquaculture.

Keywords: Artificial intelligence, Smart aquaculture, Precision fish farming, Internet of Things, Machine learning

Introduction

Aquaculture has become an increasingly important source of aquatic food, employment and rural income. However, fish farmers face several challenges, including fluctuating water quality, increasing feed costs, disease outbreaks, labour requirements, climate variability and the need to produce more fish with fewer resources. Conventional pond management often depends heavily on manual observation and farmer experience, which may not always detect rapid changes in the aquatic environment. Artificial intelligence is opening a new chapter in aquaculture by allowing farms to collect, analyse and respond to large amounts of real-time information. Recent reviews describe AI applications ranging from water-quality management and precision feeding to fish biomass estimation, disease detection, behaviour monitoring and farm automation. The concept is simple: sensors observe the pond, AI interprets the information and automated systems help the farmer respond. In the future, a fish pond may continuously monitor itself and alert the farmer before a serious problem develops.

From Traditional Fish Pond to Smart Fish Farm

Traditional fish farming generally depends on periodic measurements and visual observations. Farmers may check water colour, fish activity, feeding behaviour and basic water-quality parameters manually. Although farmer experience remains extremely valuable, occasional observations can miss sudden changes in dissolved oxygen, temperature or other environmental conditions. Smart aquaculture introduces continuous monitoring through interconnected sensors and digital platforms. IoT devices can collect temperature, dissolved oxygen, pH, turbidity and other parameters at regular intervals and transmit the information to a mobile phone or cloud platform. AI algorithms can then identify abnormal patterns and generate recommendations. This creates a shift from reactive management to predictive management. Instead of discovering a water-quality problem after fish begin showing stress, the system can potentially recognize warning signs and provide an early alert.

AI-Powered Water Quality Management

Water quality is the foundation of successful fish production. Dissolved oxygen, temperature, pH, ammonia, turbidity and other parameters directly influence fish metabolism, feeding, growth and survival. Sudden deterioration can cause stress and mortality, particularly when farmers are unable to respond quickly. Smart systems use sensors to continuously measure important parameters and transmit the information to an AI platform. Machine-learning models can identify relationships between different variables and predict potential deterioration. A 2025 study demonstrated IoT-based monitoring of temperature, dissolved oxygen, pH and turbidity in tilapia farms and used machine-learning approaches for predictive water-quality analysis. The next step is automated intervention. If dissolved oxygen begins to decline, the system can send an alert or activate aeration equipment according to predefined conditions. Similarly, abnormal temperature or pH patterns can trigger warnings before they reach dangerous levels.

Intelligent Feeding: Letting AI Decide When Fish Should Eat

Feed is one of the largest operating costs in intensive aquaculture, making efficient feeding essential for profitability. Conventional feeding may involve fixed quantities and schedules, even though fish appetite changes with temperature, dissolved oxygen, biomass, weather and growth stage. AI-powered feeding systems can combine sensor information, historical feeding records, fish behaviour and growth data to estimate the appropriate feeding quantity. Cameras can observe feeding activity, while machine-learning algorithms analyse whether fish are actively consuming feed or whether excess feed is accumulating. Research on machine-learning-based feeding strategies demonstrates the potential for optimizing feeding rates while reducing waste and environmental impacts. Automated feeders can then dispense feed at selected times or in response to algorithmic recommendations. Such systems can improve feed conversion efficiency and reduce unnecessary nutrient loading in pond water.

Table 1. AI-based feeding decision factors

Data input	What AI can determine
Fish biomass	Approximate feed requirement
Feeding behaviour	Appetite and feeding response
Water temperature	Expected metabolic activity
Dissolved oxygen	Whether feeding should be reduced or delayed
Previous feed records	Feeding trends
Fish growth rate	Adjustment of feeding quantity
Weather conditions	Potential changes in feeding behaviour

Computer Vision for Fish Health and Biomass Estimation

One of the most exciting developments in smart aquaculture is the use of cameras and computer vision. Underwater or surface cameras can continuously observe fish without requiring frequent netting or physical handling. Image-processing and deep-learning models can analyse fish size, movement, density and behaviour. Computer vision can also assist in estimating biomass, counting fish and identifying abnormal swimming patterns. Recent AI research in aquaculture specifically highlights applications in fish biomass estimation, size and weight measurement, behaviour monitoring and real-time observation. For example, if fish suddenly gather near the surface or show unusual swimming behaviour, the system could identify the event as a possible warning sign. Such information can be combined with dissolved oxygen and temperature data to distinguish between environmental stress and other potential problems.

Early Disease Detection and Fish Health Management

Disease outbreaks can cause major economic losses in aquaculture because they can spread rapidly through densely stocked populations. Conventional diagnosis often depends on visible symptoms, laboratory testing and farmer observation. AI provides an opportunity to identify warning signs at an earlier stage. Computer vision can examine changes in swimming behaviour, body appearance and feeding activity, while machine-learning models can combine these observations with water-quality information. AI research has identified disease detection and fish-health monitoring as important applications of smart aquaculture systems. Early warning does not mean that AI replaces veterinary or aquatic animal health professionals. Instead, it can act as a surveillance system that alerts farmers to investigate suspicious changes. This can support faster diagnosis, targeted intervention and reduced unnecessary use of treatments.

IoT, Mobile Apps and Real-Time Farm Management

The Internet of Things provides the communication backbone of smart fish farming. Sensors installed in ponds collect information, wireless networks transfer the data, cloud or edge-computing systems process it and mobile applications present the results in a farmer-friendly format. A farmer could potentially view pond temperature, dissolved oxygen, pH, feeding activity and equipment status from a smartphone. If a parameter crosses a predefined threshold, the application can send an immediate notification. Recent AIoT research emphasizes the combination of real-time sensor data and AI analytics for monitoring, prediction and decision-making in aquaculture. Modern systems are also moving toward automated control. Aerators, pumps, feeders and other equipment can be connected to the digital platform. However, automated actions should include safety limits and human oversight, particularly for critical farm operations.

Table 2. Smart technologies and their role in fish farming

Technology	Main function
IoT sensors	Continuous environmental monitoring
AI/ML	Prediction and decision support
Cameras	Fish behaviour and biomass observation
Mobile applications	Farmer alerts and dashboards
Automated feeders	Precision feed delivery
Smart aerators	Oxygen management
Cloud platforms	Data storage and analysis
Drones/robots	Farm inspection and monitoring

Digital Twins, Robotics and Autonomous Fish Ponds

The next generation of smart aquaculture may use digital twins, which are virtual representations of real fish farms. A digital twin can combine sensor data, environmental information, fish-growth models and operational records to represent what is happening inside a pond or production system. Research published in 2025 describes digital twins as a promising technology for real-time monitoring and optimization of water quality, feeding, fish health and farm operations. More advanced work is already exploring digital-twin monitoring systems that represent real aquaculture environments and their changing water conditions. Robotic platforms and autonomous devices could further assist with underwater inspection, equipment checking, sampling and farm surveillance. Such technologies may be especially valuable in large or intensive production systems where continuous human monitoring is difficult.

AI for Sustainable and Climate-Resilient Aquaculture

Smart fish farming is not only about producing more fish; it should also produce fish more efficiently and sustainably. AI can help reduce feed waste, optimize aeration, improve water use, identify abnormal conditions and support better resource allocation. Integrated AI, IoT and other smart technologies are increasingly being proposed as tools for sustainable aquaculture because they can improve environmental monitoring and operational efficiency. Better feeding can reduce nutrient accumulation, while intelligent aeration can avoid unnecessary energy consumption. Climate variability makes this approach even more important. Increasing temperature, irregular rainfall and changing water conditions may create additional stress for cultured fish. Predictive systems could help farmers anticipate environmental changes and adjust feeding, aeration and water-management strategies accordingly.

Challenges: Can Every Fish Farmer Afford AI?

Despite its potential, AI-based aquaculture is not without challenges. Sensors, cameras, connectivity, automated equipment and software may require considerable initial investment. Small-scale farmers may also face difficulties with electricity supply, internet connectivity, technical maintenance and data interpretation. Another major issue is data quality. AI models require reliable, representative and well-labelled datasets. Differences in fish species, pond conditions, climate and production systems can influence model performance. Recent reviews identify data availability, model accuracy, technical complexity, infrastructure and cost as important barriers to AI adoption in aquaculture. Therefore, the future should not focus only on highly sophisticated systems. Affordable sensor kits, mobile-based advisories, cooperative technology services and simple automated feeders may provide more practical entry points for small and medium farmers.

Future Perspectives and Conclusion

The future of fish farming is likely to become increasingly connected, predictive and automated. AI systems may combine water-quality sensors, cameras, weather forecasts, feeding records and fish-growth information into a single decision-support platform. Generative AI and advanced digital systems are also being explored for personalized farm advisory services, synthetic data generation, digital twins and intelligent monitoring. The vision is not a pond operating without farmers, but a farmer supported by an intelligent digital assistant. AI can monitor what humans cannot continuously observe, identify patterns hidden in large datasets and provide timely recommendations. Nevertheless, farmer experience, biological knowledge and professional judgement will remain essential. Smart fish farming therefore represents a transition from “observe and react” to “monitor, predict and act.” When AI, IoT, computer vision and sustainable management are integrated responsibly, fish ponds can become more productive, resource-efficient, environmentally responsible and resilient. The fish farmer of the future may not spend less time caring about the pond—but will have much better information about what the pond needs.

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