

## From Manual to Autonomous: The New Era of Drone Feeding Systems in Aquaculture

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### *Abstract*

Drones are revolutionizing the aquaculture industry, representing a leap forward in digital technology. This essay explores the shift from traditional manual feeding to sophisticated, autonomous aerial systems. It highlights how drones are improving precision, efficiency, and sustainability in fish and shrimp farming. By utilizing GPS, machine learning, real-time imaging, and environmental monitoring, drone feeders provide accurate feed distribution, reducing labor, costs, and environmental impact. Case studies from Ecuador, Vietnam, and India showcase improvements in water quality, biomass uniformity, and feed conversion as farmers adopt these technologies. While challenges like weather dependency, payload restrictions, regulatory hurdles, and training needs exist, drone feeding systems show great potential for wider use. The essay also discusses future innovations like drone swarms, AI-powered forecasting, integrated aerial and underwater systems, and solar-powered docking stations. These developments signal a new era where autonomous feeding is key to the smart, effective, and sustainable advancement of modern aquaculture.

**Keywords:** Automated feeder systems, feed optimization, enhanced feed conversion efficiency, sustainability.

### **Introduction**

Aquaculture is undergoing a significant change, driven by the necessity to meet the rising global appetite for seafood while reducing environmental effects and labor demands. Among the cutting-edge technologies reshaping the sector, drone-based automated feeding systems stand out as one of the most significant advancements in the last ten years. Traditionally, feeding in aquaculture, especially in shrimp and fish pond settings, has been performed manually by workers who distribute feed along the pond's edges or from boats. While this method is feasible for small family-operated ponds, it becomes inefficient, inconsistent, and costly when applied to larger commercial operations. Moreover, manual feeding has historically resulted in high feed conversion ratios (FCR), uneven distribution of feed, and increased water pollution due to either overfeeding or underfeeding (Patil & Singh, 2021). In contrast, automated drones equipped with sophisticated sensors, real-time navigation

systems, and AI-driven feed prediction models provide an unprecedented level of precision. These technologies have the potential to reduce dependency on human labor, improve feed distribution, and enhance pond health, indicating a shift “from manual to autonomous” in the everyday activities of aquaculture farms. Recent research suggests that drone-assisted feeding can decrease feed waste by as much as 20–30% and significantly improve growth performance in shrimp ponds (Loures et al., 2022). With an increasing focus from farmers, researchers, and policymakers, the drone-feeding initiative represents not just a technological enhancement but a thorough reassessment of aquaculture methods.

### **Anatomy of a Drone Feeder**

A typical automated feeding system that utilizes drones consists of several essential components that integrate effectively. Central to this system is the unmanned aerial vehicle (UAV), which can be either a quadcopter or hexacopter, depending on the payload requirements. The drone's design is crafted from lightweight carbon fiber to improve endurance while handling feed weights ranging from 3 to 15 kilograms. High-capacity lithium polymer (LiPo) batteries power the drone, enabling flight times of 15 to 25 minutes with each charge. The feeding mechanism usually comprises a hopper tank, a vibrator, and a motorized dispensing unit, which collaborate to ensure a consistent and controlled release of feed particles without the danger of clogging. Real-time sensors monitor the hopper's weight to estimate the remaining feed and prevent operational issues (Liu & Chen, 2023). The navigation system is particularly critical, incorporating GPS and GLONASS for satellite positioning, with optional RTK modules to provide centimeter-level accuracy, essential for systematic feeding across large ponds.

In more advanced systems, AI modules evaluate data collected from pond sensors; including temperature, dissolved oxygen, turbidity, and shrimp activity to adjust feeding rates dynamically. For instance, if shrimp show reduced surface activity due to molting, the system automatically lowers the feed output to minimize waste. These features together enable drones to act as smart feeding aides rather than merely mechanical distributors of feed.



**Figure 1: Drone-Based Automated Feeder**

## AI and Machine Learning in Drone Feeding

Precision feeding in aquaculture is centered on a simple principle: animals should receive exactly the nutrients they need neither more nor less. Although this method has been adopted in livestock and poultry for many years, its application in aquaculture has progressed slowly because of difficulties in monitoring feeding behavior underwater. Drone-assisted feeders solve this problem by integrating sensors, aerial imagery, and AI-based algorithms that assess proxy indicators such as shrimp aggregation on the surface, changes in turbidity, and feeding response rates. Research suggests that shrimp feeding behaviors can be estimated through observable patterns, such as rapid changes in surface ripples, swift movements toward feed shadows, and periodic feeding surges during dawn and dusk (Marques et al., 2021). High-tech drones fitted with downward-facing cameras or multispectral imaging can capture these behavioral cues from above. Machine learning techniques convert video footage into quantifiable data, enabling the drone to modify feeding in real time. For example, convolutional neural networks (CNNs) can analyze shrimp density near feeding areas and compare it to anticipated biomass, facilitating the adjustment of feed distribution (Gupta & Raman, 2022).

Besides behavior, precision feeding also takes environmental factors into account. Factors such as temperature, dissolved oxygen (DO), pH, and ammonia levels greatly affect the appetite of shrimp and fish. Under low DO conditions, which often occur at dawn, shrimp generally reduce their feed consumption naturally. Conventional feeding methods frequently overlook this, leading to feed waste. IoT sensor-connected drone systems automatically reduce feeding during these periods of stress to align feeding with biological trends and improve feed conversion ratios (FCR). A crucial aspect of modern drone feeding systems is the incorporation of AI-driven decision-making. Earlier drone feeders typically operated on fixed schedules, whereas contemporary systems utilize machine learning to constantly refine feeding strategies based on historical data. These systems analyze biomass growth, feed consumption patterns, weather conditions, and pond health metrics to predict future feed requirements (Zhang & Xu, 2022).

A common AI application in aquaculture is the long short-term memory (LSTM) network, known for its proficiency in interpreting time-sequenced data. LSTM models can forecast daily feeding needs by reviewing previous feeding sessions, biological cycles like molting, and changes brought about by environmental factors. When paired with drones, these predictions allow the system to plan optimized feeding operations each day without human intervention. Another significant AI approach is reinforcement learning (RL), where the system "learns" the most efficient feeding methods through feedback in the form of rewards and penalties. For instance, if a drone releases an excessive amount of feed and subsequent water

analyses show elevated ammonia levels, the RL model records this as a negative event and adjusts the feeding intensity for similar future circumstances (Li et al., 2023). This self-optimizing capability enables drones to become progressively more intelligent over time, ultimately outperforming human decision-making in feeding.

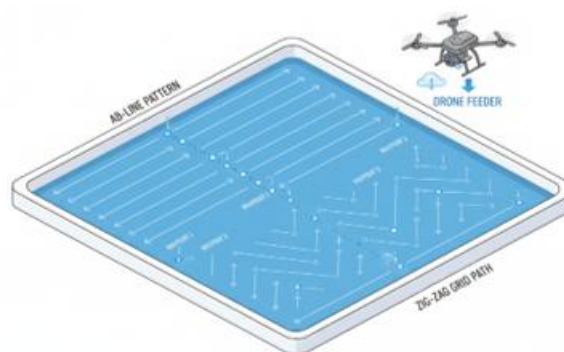


Figure 2: Path planning of drone

### Drone Feeding Improves Water Quality

Unhealthy feeding practices are a major factor in water pollution within aquaculture. An excess of feed settles at the bottom and decomposes, producing ammonia, nitrite, and hydrogen sulfide, which pose threats to the survival of aquatic species. Drone feeders help to alleviate these concerns by providing a more consistent and precise feed distribution, thus reducing the clumping of feed in particular areas. Uniform feed distribution ensures that every section of the pond receives equal feeding chances, which aids in preventing shrimp aggregation and the accumulation of organic matter on the bottom (Samocha et al., 2021).

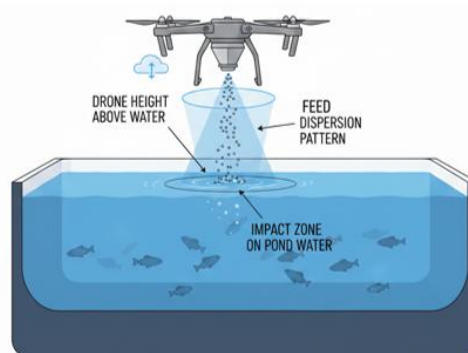


Figure 3: Drone-Pond Interaction Diagram

When animals are more evenly spaced, waste concentration decreases, and diminishes the formation of hotspots that require oxygen. Research on extensive shrimp farms in Vietnam indicates that feeding assisted by drones has led to a reduction in organic load by as much as 35% when compared to traditional manual feeding approaches (Tran & Huynh, 2023). In addition, numerous drone systems are equipped with real-time water quality sensors. These sensors communicate data directly to the drone or a cloud-based dashboard, enabling the system to pause feeding when oxygen levels are low or ammonia levels are high. This practice not only improves water quality but also protects the health of the animals during stressful situations.

### Regulatory Perspective

- Government policies play a crucial role in supporting the adoption of autonomous systems in aquaculture. Countries such as China and Japan have already created frameworks to integrate drones into agricultural and fishery operations.
- In India, where aquaculture contributes significantly to export revenue, policymakers are beginning to recognize the potential of drone-based feeding systems.
- The Indian government's "Drone Shakti" initiative promotes the use of drones in agriculture through subsidies and training programs.
- While these programs have primarily focused on crop spraying, their scope is gradually widening to include aquaculture applications.
- State fisheries departments in Andhra Pradesh and Tamil Nadu have initiated pilot studies to evaluate drone feeding efficiency in shrimp ponds, providing technical support and training to farmers.
- Regulatory compliance, however, remains essential. Farms must ensure drones are registered under the Digital Sky platform, and operators must possess the required Remote Pilot Certificate.
- For large drones with heavy feed payloads, additional safety assessments may be necessary.
- Despite these requirements, governments are increasingly supportive of drone adoption, offering pathways to integrate aerial feeding into mainstream aquaculture operations.

### **Future Innovations**

The future of aquaculture feeding is poised to move beyond simple automation toward full ecosystem intelligence. Several emerging innovations will shape the next generation of drone-based feeding systems:

#### **A) Integration with Underwater Drones**

While aerial drones handle feed distribution, underwater drones (ROVs and AUVs) can monitor shrimp movement, health, and biomass. Combined aerial-underwater systems can provide a complete 3D understanding of pond conditions, enabling precise feed prediction.

#### **B) Swarm Drones for Large Ponds**

Swarm feeding, where multiple drones collaborate like a fleet, will allow simultaneous feeding across large ponds. Coordinated swarm algorithms ensure collision-free operation and uniform pond coverage.

#### **C) Solar-Powered Charging Stations**

Solar docking stations will allow drones to recharge autonomously between feeding missions, reducing human intervention and enabling 24/7 operational readiness.

**D) Block chain-Based Feed Traceability**

E) As sustainability becomes increasingly important, block chain will enable transparent recording of feed usage, feeding schedules, and environmental data. Export markets will benefit from high traceability standards.

**F) Hyper-Precision AI Prediction**

Advanced AI models incorporating satellite data, climate trends, and real-time biological monitoring will fine-tune feeding decisions to unprecedented accuracy. Predictive models will not only determine “how much to feed” but also “when to feed” and “where to feed” for maximum growth and minimum environmental impact. These innovations will redefine aquaculture, turning traditional ponds into fully automated production ecosystems with minimal human oversight.

**Conclusion**

Automated feeding utilizing drones marks a significant advancement in the evolution of global aquaculture. Originally introduced to alleviate labor demands, this technology has evolved into a sophisticated system that enhances precision, environmental friendliness, and profitability. By integrating robotics, artificial intelligence, and environmental monitoring, drones offer aquaculture producers effective solutions to persistent issues like feed loss, uneven distribution, and declining water quality. The shift from conventional manual feeding to autonomous systems represents more than simply a technological improvement; it signifies a larger movement towards intelligent aquaculture systems aimed at meeting the growing global demand for seafood while preserving natural ecosystems. As drone technology continues to evolve, its integration into standard aquaculture practices will not only become beneficial but also essential. The future of farming will be defined by intelligence, automation, and sustainability, with drone-supported feeding playing a crucial role in this change.

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