

CHAPTER 2

Aquariculture for Economic, Social and Environmental Sustainability: The Indian Perspective of Ornamental Fish Farming

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Received: 14 September 2025; Accepted: 30 October 2025; Available online: 17 November 2025

Abstract: Aquariculture broadly encompasses aquaculture and its related practices of breeding, rearing and harvesting aquatic organisms. This has emerged as a pivotal sector in India, intertwining economic growth, social development and environmental sustainability. Geographically India is bestowed with vast coastline, extensive riverine systems, reservoirs, ponds, tanks and inland water resources that greatly potentiates the booming of the aquariculture not just as a food production industry but a multidimensional pillar of sustainability. Economically, it fuels livelihoods and exports; socially, it ensures nutrition and inclusive growth and environmentally, it

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Interdisciplinary Research in Life Sciences: A Path Towards Sustainability (Vol. 3) - Jayvardhan V. Balkhande & Jalandar Vaghmare (Eds.)

ISBN: 978-93-95369-86-2 (paperback) 978-93-95369-58-9 (electronic) | © 2025 Advent Publishing.

<https://doi.org/10.5281/zenodo.17633686>

holds potential for biodiversity conservation and eco-restoration. The appropriate policies, technological innovations and community participation are already entwining in turn heading India to a leading position in showcasing aquaculture as a model of sustainable development. This article chiefly highlights the culture of the ornamental fishes which are often referred to as the “Living Jewels”. These are the graceful creatures that boosts mood, economy and promote low-cost and effective enhancement to the livelihood of significant percentage of population globally. They are well-documented instances of the traditional axiom “small tanks can bring big fortunes”. Ornamental fish farming, in particular is referred to as “aqua-ornamental culture,” is the breeding, rearing and trade of attractive and colourful fish species kept in aquariums and garden ponds. These fishes are prized for their aesthetic appeal, colour, form and unique behaviour rather than for consumption. Some of the popular freshwater ornamental fish species in India are Goldfish (*Carassius auratus*), Guppy (*Poecilia reticulata*), Molly (*Poecilia sphenops*), Swordtail (*Xiphophorus helleri*), Angel fish (*Pterophyllum scalare*), Koi carp (*Cyprinus carpio koi*). The marine ornamental fish farming in India are economically valued; though are technologically demanding. Some of these are Clownfish (*Amphiprion spp.*), Damsel fish, Butterfly fish, Seahorses. Ornamental fish farming is a vital component of aquaculture - combining economic potential, social value and ecological importance. India is the second-largest fish producer in the world and ornamental fish farming is emerging as a niche yet growing focussing on the areas of productivity, quality, sustainability, technology infusion and income generation for fisherfolk. The PM Matsya Sampada Yojana (PMMSY), a part of the Blue Revolution is designed to modernize India’s fisheries sector. Within it, ornamental fish farming is being promoted as a sustainable, high-value and employment-generating activity.

Keywords: Aquaculture, Ornamental Fish, Sustainability, Economic, Social, Ecological

History: Aquaculture refers to the cultivation of aquatic organisms - including fish, shellfish, crustaceans, molluscs, aquatic plants and ornamental species - carried out under controlled or semi-controlled environmental conditions (Umamaheswari, 2003). The history of aquaculture dates back to the eras of Before Christ. The earliest documented aquaculture practices originated in China. The earliest known dissertation on fish farming, “*Yang Yu Ching*” authored by the Chinese statesman Fan Li has been reported to be dated back to 475 BC. This conclusively mentioned the farming of common carp as the principal species in the ancient times. It continues to be the commonest of the various carps to be farmed globally. The process of selective breeding enabled the assortment of strains with easier cultivating measures. As a result, it laid the foundation of scientific aquaculture (Edwards, 2025). Similarly, ancient Egyptians practiced fish rearing, particularly tilapia,

in ponds along the Nile. Ancient Egyptian wall paintings, particularly from tombs at Thebes, provided evidence of tilapia farming practices. In ancient Rome, wealthy citizens constructed fish ponds (*piscinae*) to raise species such as mullet, oysters and other valuable fish. Oyster farming, in particular was highly developed, employing sophisticated techniques to regulate salinity and tidal flow (Keith, 2017).

The medieval period witnessed further diversified traditions. In Europe, Christian monasteries in Central and Eastern regions cultivated carp ponds to provide food during fasting periods when meat was prohibited. Carp culture flourished in Poland, Hungary, Germany and the Czech lands becoming a staple of rural economies (Novak *et al.*, 2025). In India, traditional systems integrated fish farming with rice paddies, especially using carp, laying the foundation for integrated aquaculture practices that continue till date (Sathoria & Roy, 2022). In Japan, aquaculture took a cultural turn with the selective breeding of koi carp in the 18th century, giving rise to ornamental aquaculture (Tan, 2018). Important landmarks that brought further alleviations are those in Southeast Asia. The farmers developed integrated systems combining fish, rice, ducks and livestock that served as the earliest instances of sustainable & polyculture-based aquaculture (Devendra, 1997). By the 16th of century, Europe witnessed prime efforts to expand hatchery methods, though scientific breakthroughs came later. In 1758, Stephen Ludwig Jacobi of Germany pioneered the technique of artificial fertilization of trout eggs, that emerged as the milestone in controlled fish breeding (Orland, 2017).

As an industry, the practice flourished in the 20th Century with milestone achievements like advances in breeding, nutrition, and disease management. Development of pond culture, cage culture and raceway systems led to further expansion of species diversity with shrimp, tilapia, catfish, and salmon becoming dominant farmed species. China emerged as the global leader in aquaculture, pioneering large-scale carp, tilapia and shrimp farming. Europe & North America focused heavily on salmon aquaculture, particularly in Norway, Scotland, Canada, and Chile. Africa and Latin America adopted tilapia and catfish farming as accessible protein sources (Subasinghe *et al.*, 2009). The 21st Century gradually evolved with technological advancement - Recirculating Aquaculture Systems (RAS) for water-efficient indoor farming, Biofloc technology for sustainable shrimp and fish culture, Integrated Multi-Trophic Aquaculture (IMTA), which combines fish, shellfish, and seaweed for balanced ecosystems. The rapid growth of ornamental fish farming eventually evolved in supplying global aquarium trade with species like guppies, goldfish, koi and marine ornamentals (Tucciarone, 2024). Thus, aquaculture that began as a small-scale subsistence practice in ancient China and Egypt, expanded through Roman and medieval European systems,

advanced scientifically in the 18th - 19th centuries, and became a global industry in the 20th - 21st centuries. Today it plays a crucial role in food security, trade and livelihoods worldwide.

Aquariculture – Initial Establishment

The ancient practices as evidenced from the earlier section elaborated on the deep historical roots. The various culture of China, Egypt, Rome, India have documented the evolution of aquariculture gradually and established the cultivation of fish, prawns and ornamental species for food, trade or recreation. Establishing a modern aquariculture farm requires systematic planning, scientific management and sustainable practices to ensure profitability and environmental safety, careful planning, infrastructure, species selection, water quality management and market linkage. With scientific practices and sustainable management, aquariculture provides opportunities for food security, rural employment and profitable entrepreneurship. Thus, modern aquariculture techniques relies on **ancient practices that in turn have deep historical roots and a modern systematic process** involving site selection, pond construction, seed stocking and management (Turlybek, 2025).

Ornamental Fish Farming

Ornamental fish farming involves breeding and rearing fish species primarily for decorative purposes in aquariums and garden ponds. It's a growing sector in India, offering opportunities for small-scale entrepreneurs and hobbyists alike. The first practice of ornamental fish farming is traced back to China around 2000 years ago. The Chinese selectively bred carps (particularly *Carassius auratus*) for colour variations. This early practice led to the creation of the goldfish, which is considered the world's first domesticated ornamental fish (Balon, 1995).

Some of the key milestones achieved over the years are worth mentioning as over the eras they brought significant improvement in the farming practices of ornamental fish.

- a. The Chinese fisherman in around 200 AD noticed some colour related mutations in the wild grey carps occurring naturally in the ponds. As a result, these colourful variants were preferred to be grown separately, initially for religious purposes and later for aesthetic appreciation.
- b. The Japanese in 16th - 17th century further refined the Chinese way of breeding techniques, hence leading to varieties like **Koi carp** (*Nishikigoi*), renowned for their striking patterns.
- c. The 17th century marked the introduction of Goldfish as an exotic pet in Portugal and gradually across Europe.

- d. In India, Ornamental Fish Farming emerged as a part of aquaculture initially. The trading for pet generated revenues, hence the farming of colourful species like goldfish, guppies, mollies and koi started getting cultured in controlled ponds and tanks (Sinha, 2016).

India is fast emerging as a significant hub for ornamental fish culture, driven by its remarkable biodiversity, favourable climatic conditions, and proactive government support. The country harbours more than 400 indigenous species of ornamental fish, particularly concentrated in biodiversity-rich regions such as the North Eastern states, the Western Ghats, and the Andaman and Nicobar Islands. Its tropical and subtropical climate enables year-round breeding and rearing of diverse species, providing a natural advantage to farmers and entrepreneurs. Complementing these resources, initiatives under the Blue Revolution and PMMSY have introduced financial incentives, training and infrastructure development to promote ornamental fisheries. Together, these factors position India as a promising player in both domestic and international ornamental fish markets (Patel *et al.*, 2023).

The Indian Perspective of Ornamental Fish Farming

The practice began in India mainly during the 1960s - 70s, when goldfish, guppies and mollies were introduced as pets. By the 1980s, small-scale farms started in West Bengal and Kerala, gradually spreading to other states. Today, India is both a domestic producer (serving local aquarium markets) and an exporter, though it is still behind the countries like Singapore and Thailand. The Major Farming States are West Bengal which is the largest producer as well as hub for indigenous fish and exotic varieties. Kerala is known for the cultivation of guppies, mollies, swordtails, barbs and koi carp. Tamil Nadu & Andhra Pradesh have established the backyard and commercial farms. Maharashtra, Odisha, Assam, Manipur, Meghalaya are growing culture of indigenous species like *Danio*, barbs, loaches (Raja *et al.*, 2015).

A. The popular ornamental fish species cultured in India are broadly grouped into exotic (introduced) and indigenous (native) categories:

Exotic species: These are imported & widely cultured species that dominates the aquarium trade in India due to their hardy nature, fast breeding and high demand. These are further grouped as –

- **Livebearers**
 - Guppy (*Poecilia reticulata*)
 - Molly (*Poecilia sphenops*)
 - Swordtail (*Xiphophorus helleri*)
 - Platy (*Xiphophorus maculatus*)

- **Goldfish Varieties** (*Carassius auratus*)
 - Comet, Fantail, Oranda, Black Moor, Ranchu, Lionhead, Ryukin, etc.
- **Koi Carp** (*Cyprinus carpio*) – Nishikigoi varieties
- **Tetras**
 - Neon tetra (*Paracheirodon innesi*)
 - Black tetra (*Gymnocorymbus ternetzi*)
 - Glowlight tetra (*Hemigrammus erythrozonus*)
- **Barbs**
 - Tiger barb (*Puntius tetrazona*)
 - Rosy barb (*Pethia conchonius*)
- **Gouramis**
 - Dwarf gourami (*Trichogaster lalius*)
 - Pearl gourami (*Trichopodus leerii*)
- **Cichlids**
 - Angel fish (*Pterophyllum scalare*)
 - Oscar (*Astronotus ocellatus*)

Indigenous species: These are native to India and regions of Northeast, Western Ghats and coastal regions primarily dominate with their presence.

- **Carp & Barbs**
 - Rosy barb (*Pethia conchonius*)
 - Puntius spp. (spotted, ticto, filament, etc.)
 - Denison barb (*Sahyadria denisonii*) – highly valued
- **Danios & Rasboras**
 - Zebra danio (*Danio rerio*)
 - Giant danio (*Devario aequipinnatus*)
 - Rasbora (*Rasbora daniconius*)
- **Loaches & Catfish**
 - Glass catfish (*Kryptopterus bicirrhis*)
 - Botia loach (*Botia lohachata*)
 - Mystus spp. (catfishes with ornamental value)

- **Other Indigenous Ornamentals**

- Indian glass fish (*Parambassis ranga*)
- Spotted snakehead (*Channa punctata*) – kept in some aquaria
- Freshwater puffer (*Tetraodon cutcutia*)

Marine Ornamental Fish: These species are cultured in the Coastal India. Especially the regions of Tamil Nadu, Lakshadweep, Andaman & Nicobar and Kerala lead their presence.

- Clownfish (*Amphiprion ocellaris, A. clarkii*)
- Damselfish (*Dascyllus spp.*)
- Butterflyfish (*Chaetodon spp.*)
- Seahorses (*Hippocampus spp.* - under regulation) (Athithan & Nadu, 2021)

B. Blue Revolution and Ornamental Fish Farming in India

The Blue Revolution refers to the rapid increase in fish production in India through modernization of fisheries and aquaculture. It was launched in the 1970s, with stronger emphasis under Blue Revolution 2.0 (2015 onwards) and PMMSY, 2020. The objective was to enhance fish production, increase farmers' income, generate employment and upsurge the exports (Lakra & Gopalakrishnan, 2021).

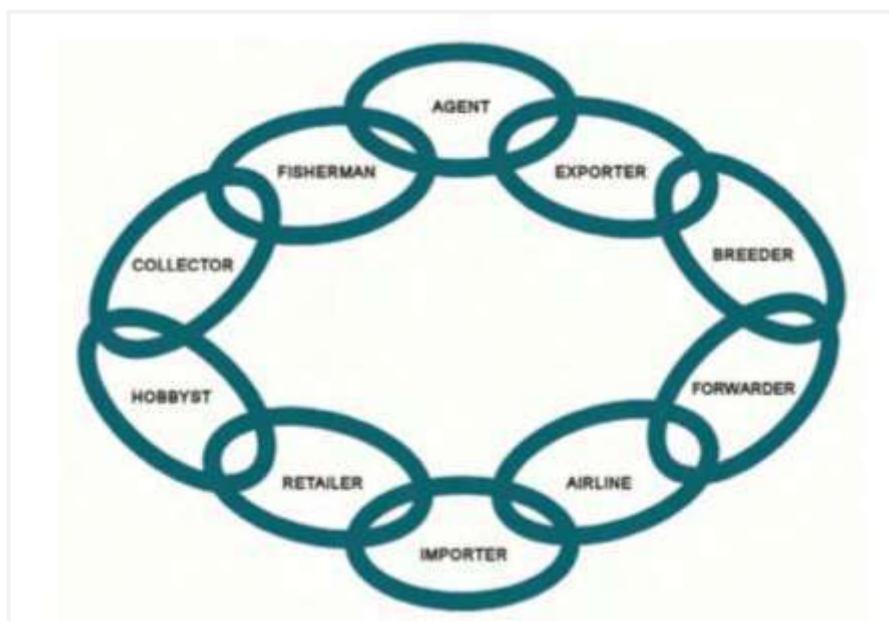


Figure 1: The depiction of value chain/supply chain in the ornamental fish trade. The different stake-holders are involved suggesting the possible achievement of the conceived objective (Monticini, 2010).

The PMMSY is the developmental scheme that aimed at “Blue Revolution through sustainable and responsible fisheries development” through direct support for people *viz.*, livelihoods, units, subsidies. The FIDF (Fisheries and Aquaculture Infrastructure Development Fund), launched in **2018-19**, aimed to provide **financial assistance (loan-based)** or Infrastructure Financing Fund for fisheries infrastructure creation. It targets States, UTs, cooperatives and private entrepreneurs. Hence, FIDF gives indirect Ornamental Fish Coverage like public projects e.g., public aquariums and retail units in Tirunelveli, Tamil Nadu. The public aquarium and ornamental fish retail unit of Tirunelveli, Tamil Nadu, India is worth Rs. 5.00 crore project approved under FIDF as of April 2025. This initiative, supported by the National Fisheries Development Board (NFDB) aimed to promote ornamental fisheries and contribute to employment and entrepreneurship in the region (Pandey, 2025).



Figure 2: The public aquarium and ornamental fish retail unit of Tirunelveli, Tamil Nadu

The Blue Revolution in India marked a turning point in fisheries development, transforming it into a major contributor to livelihood, nutrition and exports. It has positioned ornamental fish farming as a profitable, eco-friendly and export-oriented sector, further strengthening under PMMSY through subsidies, infrastructure, training and market linkages. This sector blends livelihood generation, biodiversity conservation and international trade.

The scheme focused on enhancing production and productivity of inland and marine fisheries, while ensuring the participation of economically weaker groups such as SCs, STs, women and cooperatives. It encouraged entrepreneurship, private investment and institutional finance to

expand fisheries as a viable enterprise. The Department of Fisheries (DoF) and the National Fisheries Development Board (NFDB) played key roles in implementation. NFDB provided technical guidance to 27 States and 7 UTs, scrutinized projects on techno-financial grounds, and facilitated funding for states, ICAR institutes and KVKs. The mission also contributed to food and nutritional security by augmenting fish production in a sustainable manner (GOI, PIB, 2025 <https://www.pib.gov.in/PressNoteDetails.aspx?NotelId=155173&ModuleId=3>).

Key interventions included the adoption of a cluster-based approach for water resource development, post-harvest and marketing infrastructure and need-based livelihood support. Modern technologies such as cage culture and RAS were introduced as models of intensive fish production. Importantly, the Blue Revolution gave special emphasis to ornamental fisheries, supporting breeding, culture and trade, thereby boosting both domestic markets and exports. Thus, the Blue Revolution has not only increased fish production but also strengthened rural livelihoods, promoted innovation and established India as a growing hub for ornamental fish farming (Chouhan & Choudhary, 2025).

Recent government initiatives (2024-2025) under the PMMSY highlight the growing emphasis on ornamental fisheries as a driver of aquaculture-led economic growth. Between 2020 and 2025, the sector received over \$18.8 million (₹157.64 crore) in financial support, facilitating the establishment of backyard units, medium-scale rearing farms, and integrated facilities. In 2024 - 25, Madurai district in Tamil Nadu was officially designated as an Ornamental Fisheries Cluster to strengthen entrepreneurship, infrastructure and market access (Vincent & Saravanan, 2020). Other key developments include approval for an indigenous fish aquarium in Assam and the assignment of ICAR - CIFA to prepare a comprehensive roadmap for ornamental fisheries growth and value-chain enhancement (Sahoo *et al.*, 2023). Additionally, breeding and rearing projects have been sanctioned in states such as Madhya Pradesh and Rajasthan (Pandey, 2025). A noteworthy technological advancement was the launch of the Rangeen Machhli mobile app in November 2024, designed to deliver knowledge resources to hobbyists, aquarium traders and ornamental fish farmers (Chakra, 2024).

C. Status of Ornamental Fish Trade in India

India has rich ornamental fish biodiversity and strong domestic demand, but its global trade share remains small (<1%). With PMMSY support, improved infrastructure and focus on exports, India is poised to become a significant player in the international ornamental fish market. In the global Market, Ornamental Fish farming is valued at USD 18-20 billion. However, India's share accounts to <1%. India is still emerging as an exporter; West Bengal being the main hub, followed by Kerala,

Tamil Nadu, and Maharashtra (Sinha, 2020). With statistical data suggesting exports of worth ₹6–8 crore annually, India chiefly trades to Singapore, Thailand, Japan, USA, UK, and Germany. The key species being barbs, danios, loaches, gouramis, cichlids, goldfish. The domestic market of ornamental fish farming is valued at ₹500-600 crore, growing 10 - 12% annually due to increasing aquarium hobby and urban demand (Jain *et al.*, 2025). There are potential challenges - limited hatcheries, transport mortality, lack of quarantine/certification, limitation in adopting breeding technologies etc. However, government assistance through PMMSY & Blue Revolution are alleviating subsidies, ornamental fish villages, training; in turn leading to export promotion.

Place	Rate of success (%)	Earnings (₹ /women/month)
Chunakoli, Bhubaneswar, Odisha	93	1,000-2000
Satyabansapur, Cuttak, Odisha	68	800-1,200
Kaliana, Bhubaneswar, Odisha	84	1,000-1,600
Bashia, Balasore, Odisha	36	150-650
Miyurbani, Odisha	51	250-300
Antoli, Sundarban, WB	56	550-1,300
Kaltali, Sundarban, WB	76	1,000-1,500
Khalsi, Nadia, WB	44	300-900
Ranchi, Jharkhand	64	200-700
Jamshedpur, Jharkhand	88	850-1800
Bokaro, Jharkhand	47	150-350
Surgachi, Murshidabad, WB	56	100-300
Habibpur, Malda, WB	68	200-250
Mirik, Darjeeling, WB	54	350-450
Simdega, Jharkhand	24	Not Started yet
Sukhia Pokhri, Darjeeling, WB	13	Not Started yet
Sitong, Darjeeling, WB	68	550-700
Kochukhali, Sundarban, WB	10	Not Started yet

Figure 3: Area-specific success rate and women's income generated from ornamental fish farming (Bhattacharya *et al.*, 2025)

D. Sustainable Ornamental Fish Farming

Sustainable ornamental fish farming is an approach that harmonizes economic development with environmental stewardship. It ensures that while the sector grows profitably, it does not compromise ecological balance or biodiversity. By adopting practices such as captive breeding of native species, responsible collection, efficient water management and eco-friendly technologies like recirculating aquaculture systems, it reduces the negative impact on natural ecosystems. At the same time, it creates livelihood opportunities for rural communities, women and youth promoting social inclusion and entrepreneurship. This balance between profitability, inclusivity and ecological

responsibility makes sustainable ornamental fish farming a vital component of modern aquaculture, aligning with both conservation goals and market demands (Shyam *et al.*, 2013).

E. Important practices employed in Ornamental Fish Farming

The successful practice of ornamental fish farming relies on aquaculture techniques with aesthetic considerations. Successful operations rely on a blend of biological knowledge, environmental control and sustainable practices.

Aspect	Key Practices
Species & Breeding	Starting with easy-to-breed livebearers; maintaining genetic diversity and focusing on one species initially.
Infrastructure	Using cost-effective containers; choosing shaded, water-and-electricity-accessible locations.
Water Management	Keeping the pH & temperature stable; utilizing filtration and RAS for efficiency and hygiene
Feeding	Providing live feeds & local feed; avoiding overfeeding to maintain water quality
Disease Control	Quarantine of new stock; maintaining hygiene and utilization of enclosed systems like RAS
Monitoring	Tracking the breeding, health, water, and growth to refine operations
Marketing & Sustainability	Ensuring transport access; diversification of markets; adopting sustainable & eco-friendly methods

By embracing the cutting-edge technologies - from IoT automation and ML-driven insights to innovative filtration systems and smart materials - ornamental fish farms can achieve smarter, more sustainable and efficient operations (Patro *et al.*, 2023). These smart technologies are enhancing fish well-being, reducing resource uses and elevating the ease of farm management.

1. IoT-Based Automations, Remote Monitoring & Data Analytics

Automated Feeding Systems: The automated feeding systems using IoT and microcontrollers can schedule feed quantity and dispenses it as per the schedule designed. The entire process is based on fish behaviour and the water conditions as well. This improves feeding accuracy and attenuates manual workload. The IoT-enabled automatic fish feeder is a smart system that uses a microcontroller such as an Arduino or ESP32/ESP8266 with Wi-Fi connectivity to automate the process of dispensing fish food. The feeder is equipped with a dispensing mechanism operated by a servo or stepper motor to release measured portions of food at scheduled times, with accuracy

ensured by a real-time clock (RTC) module. Through IoT integration, the device can be connected to cloud platforms or mobile applications, allowing users to remotely monitor and control feeding operations. Advanced versions may also include sensors to track food levels or water quality, enabling data-driven adjustments for healthier fish and reduced waste. By minimizing manual effort, preventing overfeeding, and ensuring consistency, the system is highly beneficial for both ornamental fish keepers and commercial aquaculture farmers.

Remote Monitoring: The IoT aquaculture provides real-time insights into fish farming operations. The sensors are placed in water tanks or ponds that continuously monitors vital parameters *viz.*, temperature, pH levels, dissolved oxygen and salinity. The data is transmitted to the centralized system, where further analysis is done to detect anomalies or investigate the trend. Example: If oxygen level drops below a certain threshold, the system gives alert allowing interventions for corrective action before any fish is harmed. This proactive approach lessens the risk of mass mortality and safeguards optimal growing conditions.

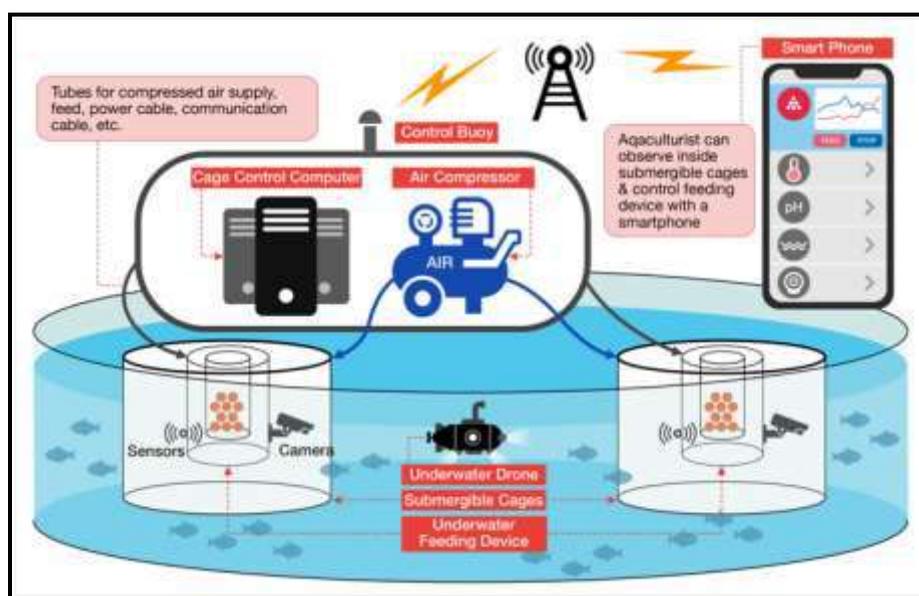


Figure 4: Concept diagram of smart aquaculture system (Vo *et al.*, 2021)

2. AI & Machine Learning for Smart Decision-Making

Predictive Behavioral Analysis: Predictive behavioral analysis relies on technologies like machine learning, computer simulation and IoT to monitor and interpret fish behaviour. The aim is to predict and categorize potential problems - fish health, factors inducing stress, growth, and environmental conditions before they escalate. Machine learning classifiers such as decision trees,

support vector machines (SVMs), Naïve Bayes and k-nearest neighbors (KNN) have been extensively employed to model and predict fish behavioral states, including resting, erratic locomotion and surface gasping. These predictive frameworks typically utilize fluctuations in abiotic parameters - most notably water temperature and dissolved oxygen concentration - as input features. By facilitating the early detection of stress-induced anomalies, such approaches contribute to proactive management strategies, thereby enhancing fish welfare, reducing mortality risk, and supporting sustainable aquaculture practices. Advanced aquaculture management systems increasingly integrate Internet of Things (IoT) sensor networks with machine learning (ML) models - such as Random Forests, support vector machines (SVMs), gradient boosting algorithms, and artificial neural networks - to enable real-time environmental optimization. These hybrid frameworks facilitate automated regulation of feeding schedules, early detection of disease-associated behavioural or physiological signals, dynamic adjustment of critical water quality parameters (e.g., temperature and pH), and intelligent control of mechanical components such as pumps, aerators, and heaters. By maintaining consistently optimal conditions, such systems minimize stress, enhance growth performance, and improve overall sustainability in ornamental fish farming.

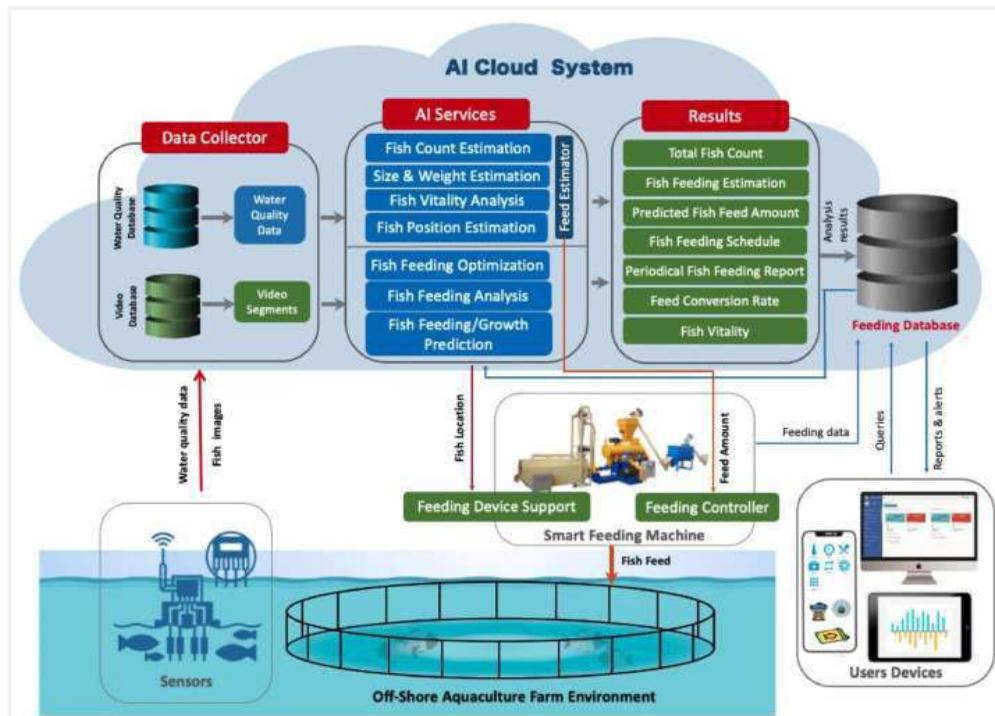


Figure 5: Overview of Intelligent Aquaculture System (Ubina *et al.*, 2023)

3. Networking for Smarter Coverage

In smart ornamental fish farming, both broadband and Narrowband-IoT (NB-IoT) networks play complementary roles. Broadband networks, including Wi-Fi and 4G/5G, deliver high-speed and reliable connectivity suited for data-intensive applications such as real-time video monitoring or cloud-based analytics. In contrast, NB-IoT supports low-power sensors that transmit small amounts of data efficiently over extended distances, making it ideal for continuous monitoring of water quality and environmental parameters.

4. Low-Cost Sensors for Broader Adoption

The low-cost sensors for ornamental fish farming are IoT based and involves affordable components like Arduino and ESP32 microcontrollers. The DIY and pre-packaged kits allow monitoring of critical water parameters in real time without needing expensive commercial-grade equipment. These sensors are often held together into a single monitoring system and linked to an IoT platform via Wi-Fi or LoRa for remote access. Few worth mentioning in this context are DS18B20 model (common and affordable waterproof option used as temperature sensor); DF Robot Analog pH sensor in integration with microcontrollers such as Arduino used as pH sensor; low-cost galvanic probes used as Dissolved oxygen (DO) sensor; infrared photodiode used as turbidity sensor; TDS sensor for total concentration of dissolved substances in the water; low-cost versions of water sensor uses infrared light emission and reception to determine the water level and low-cost IoT systems that integrates automated fish feeders using servo motors and relays. These sensors act as early warning systems, enables continuous monitoring, are affordable, are low cost, improves fish health and yield and can be scaled as per requirement.

5. AI-Driven Decision Making & Automation

The smart environmental control system uses real-time sensor data and machine learning (ML) algorithms to automate and optimize the tank or pond environment. The raw sensor data obtained is directed to various ML models. They are designed in such a way that it identifies patterns and predict optimal conditions. Common algorithms include Random Forests (predicts & optimizes temperature, pH levels), Support Vector Machines or SVMs (function as an early warning system to detect diseases and parasites in fish images), Gradient Boosting Machines or GBMs (dynamically adjust the feeding schedule based on current environmental data), Neural Networks (manages and controls automated equipment like pumps and heaters to maintain the desired environment), Decision Tree Classifiers uses sensor data to identify stress from environmental changes by focussing on fish behaviour like erratic swimming, resting (Dhenuvakonda & Sharma, 2020).

Conclusion

The key aspects of ornamental fish farming are conservation of native species by employing captive breeding; relying on eco-friendly systems like RAS; following standard sample collection methods like regulating wild catch, avoiding destructive methods, and adopting certification for sustainable sourcing; capacity building by training farmers/hobbyist in disease management, breeding, and transport practices to reduce mortality; cluster development through establishment of ornamental fish villages and common facilities for collective rearing, marketing, and exports; livelihood and social inclusion by engaging women, youth, and SHGs for employment and entrepreneurship and meeting global standards by following quarantine & certification systems that can meet international norms. These align with the goals of sustainable agriculture and aquaculture by balancing economic viability, environmental conservation, and social equity. The farming of ornamental fishes is based upon simple starting techniques employing minimal techniques & technologies, smart expansion based on innovative automation techniques and advancement as high-tech farms for economic yield using AI.

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