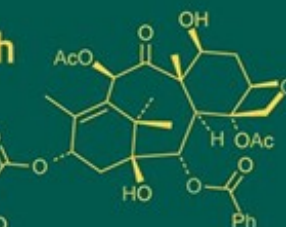
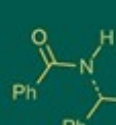


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
Indexing: Embase
IJABR 2026; 10(10): 35-38
www.biochemjournal.com
Received: 23-08-2026
Accepted: 22-09-2026
Published: 02-10-2026

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Rooftop ornamental fish culture: A sustainable urban aquaculture model for livelihood diversification and efficient utilisation of rooftop spaces

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i10a.10279>

ABSTRACT

Rapid urbanisation, increasing land prices and declining availability of conventional agricultural land have created a need for alternative production systems that can function within limited urban spaces. Rooftop aquaculture represents an emerging component of urban agriculture in which underutilised rooftop areas can be converted into productive aquaculture units. Ornamental fish culture is particularly suitable for such systems because it can be undertaken at relatively small scale and produces high-value live organisms rather than bulk biomass. Species such as guppy (*Poecilia reticulata*), molly (*Poecilia spp.*), platy (*Xiphophorus maculatus*), swordtail (*Xiphophorus hellerii*), goldfish (*Carassius auratus*), koi (*Cyprinus carpio*), gourami, angelfish and selected tetra species can be cultured in appropriately designed rooftop systems. Government-supported programmes indicate increasing recognition of ornamental fisheries as a livelihood activity in India. During 2020–21 to 2024–25, 2,465 ornamental fish rearing units and 207 integrated ornamental fish breeding and rearing units were approved under fisheries-development interventions. India exported approximately 90.97 tonnes of live ornamental fish valued at US\$2.11 million in 2024, while imports were approximately 78.94 tonnes valued at US\$2.38 million. A rooftop ornamental fish unit can combine breeding tanks, nursery tanks, grow-out tanks, filtration, aeration, quarantine and water-recycling facilities within a compact area. However, structural safety, waterproofing, temperature management, electricity, water quality, biosecurity and market access are critical factors. This review discusses the concept, design, species selection, production management, economics, environmental benefits, challenges and future prospects of rooftop ornamental fish culture as a sustainable urban aquaculture model.

Keywords: Rooftop aquaculture, Ornamental fish, Urban aquaculture, Recirculating aquaculture, Livelihood, Water recycling, Urban farming

1. Introduction

Rapid urbanisation has increased pressure on agricultural land and increased the value of land available for food production. At the same time, cities contain considerable underutilised spaces such as rooftops, terraces, balconies, courtyards and institutional premises. Urban aquaculture provides an opportunity to utilise such spaces for aquatic production. Recent literature has recognised rooftops and other unconventional urban spaces as potential locations for small-scale aquaculture and integrated food-production systems (Roan *et al.*, 2026) [1].

Rooftop farming has already emerged as a component of urban agriculture, particularly in areas where land availability is limited. Extending this concept to aquaculture provides an opportunity to produce fish close to urban consumers. Rooftop aquaculture can be operated using tanks, plastic or fibre-reinforced containers and recirculating aquaculture systems (RAS), thereby avoiding the need for conventional ponds.

Among different forms of urban aquaculture, ornamental fish culture has particular potential. Ornamental fish are generally marketed based on colour, body shape, fin characteristics, rarity and size rather than biomass. Consequently, relatively small production units can generate products with higher value per unit volume compared with conventional food-fish production. Common species include guppy, molly, platy, swordtail, goldfish, koi, gourami, angelfish, tetra and betta.

India has an established ornamental-fish industry and a growing institutional focus on ornamental fish as an entrepreneurial activity. The Department of Fisheries, Government of India, reported approval of 2,465 ornamental fish rearing units and 207 integrated ornamental fish breeding and rearing units during 2020–21 to 2024–25. The combined project cost reported for these ornamental-fish interventions was ₹230.45 crore (Department of Fisheries, 2025) [2].

International trade also indicates an established market. WITS/UN Comtrade data show that India exported approximately 90,970 kg of live ornamental fish valued at about US\$2.107 million in 2024 [3], whereas imports were approximately 78,942 kg valued at about US\$2.383 million. These figures represent international trade recorded under the relevant commodity classification and do not represent the complete domestic ornamental-fish market.

In this context, rooftop ornamental fish culture can be considered a potential urban enterprise combining aquaculture, entrepreneurship, efficient space utilisation and direct access to consumers.

2. Concept and design of rooftop ornamental fish culture

Rooftop ornamental fish culture refers to the breeding, nursery rearing and grow-out of ornamental fish in suitable tanks installed on structurally appropriate rooftops or terraces. The system may range from a few tanks operated as a small household enterprise to a commercial modular unit containing several breeding and rearing tanks.

The most important consideration before installation is structural safety. Water weighs approximately 1 kg per litre; therefore, even a 1,000-L tank contains about 1 tonne of water, excluding the weight of the tank, stand, filtration equipment and other materials. A qualified structural engineer should assess the building before tanks are installed.

A modular system consisting of several relatively small tanks is generally preferable to a few very large tanks. It allows different species and life stages to be maintained separately and limits the impact of disease or equipment failure.

Major components

- **Broodstock tanks** – maintenance of selected healthy breeding fish.
- **Breeding tanks** – controlled spawning and reproduction.
- **Nursery tanks** – rearing of fry and early juveniles.
- **Grow-out tanks** – production of market-sized ornamental fish.
- **Quarantine tanks** – isolation of newly introduced fish.
- **Filtration system** – mechanical and biological treatment.
- **Aeration system** – maintenance of dissolved oxygen.
- **Water-storage tank** – storage of treated water.
- **Packing area** – grading and preparation for transportation.
- **Optional aquaponic section** – integration with plants.

3. Selection of ornamental fish species

Species selection should consider climate, water quality, breeding characteristics, availability of broodstock, local market demand and technical skill.

Potential ornamental fish species for rooftop culture

Several ornamental fish species are suitable for rooftop culture because of their small size, attractive appearance, adaptability to captive conditions, and relatively simple breeding requirements. Guppy (*Poecilia reticulata*) is one of the most suitable species because it is a live bearer, prolific breeder, and can reproduce readily in small culture tanks. Molly (*Poecilia* spp.) is another hardy live-bearing species that adapts well to aquarium and tank conditions. Platy (*Xiphophorus maculatus*) is highly suitable because of its attractive colour varieties, easy breeding, and relatively low management requirements. Swordtail (*Xiphophorus hellerii*) can also be cultured on rooftops due to its attractive body form and diverse colour patterns.

Goldfish (*Carassius auratus*) has high ornamental value and good market demand, but it requires adequate tank volume and appropriate water quality because of its larger body size and waste production. Koi (*Cyprinus carpio*) is a high-value ornamental carp and can provide good economic opportunities; however, its culture on rooftops should be undertaken only where the building has sufficient structural

load-bearing capacity and appropriately designed tanks. Gourami species are also suitable because of their attractive colours and relatively adaptable nature. Angelfish (*Pterophyllum scalare*) can be produced as a higher-value aquarium species, although it requires comparatively better water-quality management and greater technical skill.

Small-bodied aquarium fishes such as tetra species (*Tetra* spp.) are suitable for rooftop production because they require relatively limited space and have strong ornamental-market appeal. *Betta* (*Betta splendens*) is particularly suitable for specialised rooftop production because of its high ornamental value, diverse colour forms, and ability to be maintained in relatively small individual containers. Overall, live-bearing species such as guppy, molly, platy, and swordtail are particularly appropriate for small-scale beginner rooftop units, whereas goldfish, koi, angelfish, gourami, tetra, and betta can be incorporated according to available space, structural capacity, water-management facilities, technical expertise, and market demand.

4. Water quality and production management

Water quality is one of the most important factors affecting ornamental fish production. High stocking densities, uneaten feed and faecal matter can rapidly increase ammonia and organic loading.

Important parameters include temperature, pH, dissolved oxygen, ammonia, nitrite, nitrate, hardness and alkalinity. There is no single water-quality range suitable for every ornamental species; therefore, species-specific requirements should be followed.

General water-quality management

Water quality is a critical factor in rooftop ornamental fish culture because fish are maintained in relatively small and often high-density tanks where water-quality deterioration can occur rapidly. Temperature should be maintained according to the requirements of the cultured species, while sudden temperature fluctuations should be avoided. pH should remain stable within the species-appropriate range, as rapid changes can stress fish and affect their physiological functions. Adequate dissolved oxygen should be maintained through continuous or appropriately scheduled aeration, particularly during high stocking densities and warm weather.

Toxic nitrogenous compounds require particular attention in rooftop systems. Ammonia and nitrite should be maintained as close to zero as practically possible through proper feeding, biofiltration, regular monitoring, and partial water exchange. Nitrate should also be controlled to prevent excessive accumulation over time. Water hardness should be maintained according to the requirements of the cultured species, while adequate alkalinity is important for maintaining buffering capacity and preventing sudden pH fluctuations. Chlorine present in municipal or treated water can be harmful to ornamental fish; therefore, water should be appropriately dechlorinated or conditioned before fish are exposed to it. Overall, regular water-quality monitoring, adequate aeration, biological filtration, controlled feeding, and timely water exchange are essential for maintaining a stable environment in rooftop ornamental fish culture systems.

Rooftop systems face greater temperature variation than indoor or ground-level systems. Direct solar radiation can raise water temperature, particularly in shallow dark-coloured tanks. Shade nets, lightweight roofing, reflective surfaces, insulation and suitable tank placement can reduce thermal stress.

Feeding

Feed should be provided according to species, fish size, stocking density and temperature. Commercial flakes and micro-pellets are widely used, while *Artemia*, *Moina* and *Daphnia* can be useful for selected larvae and juveniles.

Overfeeding should be avoided because uneaten feed contributes to ammonia and organic waste. Small quantities offered according to feeding response are preferable. Feed records can assist in controlling feed costs and maintaining water quality.

5. Breeding and nursery management

Breeding represents one of the most important value-generating activities in ornamental fish culture. In contrast to food-fish farming, commercial value may be generated through colour varieties, fin development, body shape and selective breeding.

Guppy, molly, platy and swordtail are live-bearing species that can reproduce successfully in relatively small tanks. Healthy broodstock should be selected and maintained under suitable water-quality and nutritional conditions. Pregnant females can be transferred to maternity tanks where necessary, and fry should be protected from predation.

Egg-laying species require different breeding systems. Spawning mops, aquatic plants, breeding cones or suitable substrates may be used according to species. Some species require separation of adults from eggs or larvae, whereas others provide parental care.

The nursery phase is critical because newly produced fry are sensitive to poor water quality and inappropriate feeding. Appropriate stocking density, regular water-quality monitoring and grading are necessary to obtain uniform juveniles.

Selective breeding can improve desirable traits such as colour, pattern, fin shape and body form. However, breeding programmes should avoid excessive selection that compromises fish health or welfare.

6. Recirculating aquaculture system and aquaponic integration

A rooftop ornamental fish unit can be operated using a recirculating aquaculture system. In a basic RAS, water moves from culture tanks through mechanical and biological filtration and is subsequently returned to the tanks.

Mechanical filtration removes suspended solids, while biological filtration provides a surface for nitrifying microorganisms. These bacteria convert toxic ammonia into nitrite and subsequently nitrate. Regular removal of accumulated solids remains necessary.

RAS can reduce water consumption compared with systems based entirely on frequent water replacement, although it does not eliminate water use. Water is still required for evaporation, cleaning, filter maintenance and partial exchange.

Rooftop ornamental fish culture can also be integrated with aquaponics. Fish-derived nutrients can support plant growth, while plants and associated biological processes contribute to nutrient removal. This may allow ornamental fish, aquatic plants, herbs and vegetables to be produced within the same rooftop enterprise.

However, aquaponic integration requires appropriate hydraulic design and nutrient balancing. It should therefore be considered an additional production component rather than a substitute for proper water-quality management.

7. Biosecurity, fish health and welfare

Biosecurity, disease prevention and fish welfare

Biosecurity is an essential component of rooftop ornamental fish culture because fish may be sourced from multiple suppliers and are often maintained at relatively high stocking densities. Newly purchased or introduced fish should therefore be quarantined before being transferred to the main production system. Quarantine facilities should preferably be separated from the main culture tanks, with dedicated nets, containers and other equipment to minimise the risk of disease transmission.

Effective biosecurity should include regular water-quality monitoring, removal of dead or moribund fish, proper cleaning and sanitation of tanks, avoidance of excessive stocking densities, controlled movement of fish and equipment, and responsible disposal of potentially contaminated water. Equipment used in quarantine should not be shared with healthy fish without appropriate cleaning and disinfection. Disease prevention should be prioritised over routine chemical treatment because poor water quality, overcrowding, inadequate nutrition and handling stress can increase the susceptibility of ornamental fish to disease. Larcombe *et al.* (2024) [4] highlighted the importance

of disease management across ornamental-fish production and supply chains.

Fish welfare should also be incorporated into rooftop ornamental fish production. Appropriate stocking density, stable water quality, balanced nutrition, careful handling and suitable transport conditions are important for maintaining fish health and reducing stress. Producers should also maintain proper records of fish movement, mortality and disease incidents to support effective biosecurity management. Ornamental fish should never be released into natural water bodies, as escaped or deliberately released non-native species may establish populations, compete with native organisms or introduce pathogens, creating ecological risks.

8. Marketing and economic potential

Marketing is a major determinant of the success of ornamental fish enterprises. Potential markets include aquarium shops, hobbyists, pet stores, wholesalers, online businesses, institutions, hotels and offices. Direct marketing through social-media platforms can reduce dependence on intermediaries. Producers can display fish varieties online and receive advance orders. Premium prices may be obtained for rare colour strains, healthy broodstock and well-graded fish.

The economic structure of a rooftop unit includes:

Table 1. Major cost components

Capital/recurring component	Importance
Structural assessment/modification	High and site-specific
Culture tanks	High
Filtration and aeration	High
Plumbing and water storage	Moderate
Broodstock	Moderate
Feed	Recurring
Electricity	Recurring
Water and maintenance	Recurring
Packaging and transport	Recurring
Labour	Variable
Marketing	Variable

Because rooftop buildings and production systems differ substantially, a universal cost estimate is inappropriate. Financial feasibility should be calculated for each site based on tank number, species, survival, breeding output, selling price, feed consumption, electricity requirements and labour.

For ornamental fish, value generated per unit of rooftop area may be more meaningful than total fish biomass. This makes species selection and quality management particularly important.

9. Environmental and livelihood benefits

Rooftop ornamental fish culture can provide several potential benefits. It utilises existing urban infrastructure and reduces dependence on additional land. RAS can improve water-use efficiency, while integration with plants can facilitate nutrient recovery.

Production near consumers may also reduce the distance between producer and market for locally sold fish. However, sustainability depends on the complete production system because electricity consumption, plastic materials, feed production and transportation also have environmental impacts.

From a livelihood perspective, ornamental fish culture can generate income through several activities, including broodstock sales, fry production, juvenile sales, premium colour varieties, aquarium plants, accessories and technical services.

Government programmes have increasingly recognised ornamental fisheries as an entrepreneurship opportunity. The approval of thousands of ornamental-fish units under fisheries-development programmes indicates expanding institutional support in India (Department of Fisheries, 2025) [2].

10. Future prospects

The future of rooftop ornamental fish culture will depend on the development of low-cost, lightweight and energy-efficient production systems. Solar-powered aeration, automatic feeders, water-quality sensors and mobile monitoring systems can improve management.

Digital technologies can monitor temperature, pH, dissolved oxygen and water level and provide alerts when parameters move outside predetermined limits. Artificial intelligence and computer vision may eventually assist in fish behaviour monitoring, biomass estimation, feeding decisions and disease detection.

India's large ornamental-fish biodiversity provides an additional opportunity. Greater emphasis on captive breeding of indigenous ornamental species could simultaneously support commercial production and conservation.

The concept may be particularly valuable in metropolitan areas where land prices are high but aquarium markets are concentrated. Educational institutions, urban farms, self-help groups and small entrepreneurs can also use rooftop units as demonstration and training facilities.

11. Discussion

Rooftop ornamental fish culture represents a convergence of urban agriculture, aquaculture technology and livelihood diversification. Its main advantage is the ability to produce high-value aquatic organisms in a relatively small area close to consumers.

Unlike conventional food-fish farming, ornamental fish production is strongly influenced by appearance, colour, rarity, size and quality. Consequently, a successful rooftop unit should focus on breeding quality, survival, grading and market-oriented production rather than simply maximising stocking density.

The expansion of Government-supported ornamental-fish infrastructure in India demonstrates increasing recognition of the sector. International trade data further demonstrate that India is both an exporter and importer of ornamental fish. However, rooftop culture should not be considered automatically profitable. Structural modification, electricity, filtration, climate management and skilled labour can increase costs.

Therefore, site-specific feasibility assessment is essential. Structural safety should be considered before production economics. The enterprise should then be designed around suitable species, reliable markets, appropriate technology and realistic production capacity.

12. Conclusion

Rooftop ornamental fish culture offers a promising approach for utilising underused urban spaces for high-value aquaculture production. The integration of breeding tanks, nursery systems, filtration, aeration,

quarantine facilities and water recycling can create a compact production unit suitable for urban entrepreneurship.

The model has particular potential for youth, women entrepreneurs, self-help groups, aquarium businesses and educational institutions. Its success, however, depends on structural safety, appropriate species selection, water-quality management, temperature control, biosecurity, reliable electricity and effective marketing.

Future development should focus on low-cost rooftop RAS, solar-powered systems, indigenous ornamental fish breeding, digital monitoring, aquaponic integration and scientifically validated economic models. With appropriate planning and responsible management, rooftop ornamental fish culture can become a useful component of smart urban aquaculture, livelihood diversification and efficient utilisation of limited urban space.

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How to cite this article: Syed Saidoddin SH, Patel DSKM, Acharya DKV, Vaichalkar AA, Kamble SN. Rooftop ornamental fish culture: A sustainable urban aquaculture model for livelihood diversification and efficient utilisation of rooftop spaces. *International Journal of Advanced Biochemistry Research*. 2026;10(10):35-38. doi: <https://www.doi.org/10.33545/26174693.2026.v10.i10a.10279>