



Research Paper

Comparative Evaluation of Self-Sustaining and Artificial Aquarium Systems with Emphasis on Water Quality and System Stability

Amrita Dwivedi and Vandana Ram*

Department of Fisheries Science, Pandit Shambhu Nath Shukla University, Shahdol, Madhya Pradesh, India

*Corresponding author email: vapfdtsnsu@gmail.com

Received: 02/09/2026

Revised: 09/09/2026

Accepted: 18/09/2026

Abstract: The present study comparatively evaluated self-sustaining and artificially maintained aquarium systems with emphasis on temporal water-quality stability. Eight experimental aquaria were used, comprising four replicate self-sustaining tanks and four artificial tanks, maintained under comparable laboratory conditions. Fifteen observation periods were recorded from 1 April to 25 June 2026. Temperature, pH, ammonia and total hardness were monitored, and descriptive statistics including mean, standard deviation and coefficient of variation (CV) were used to assess temporal variability. The self-sustaining system incorporated aquatic plants and biologically active substrate, whereas the artificial system relied on mechanical aeration and filtration. Temperature was $27.39 \pm 0.78^{\circ}\text{C}$ in the self-sustaining system and $27.44 \pm 0.66^{\circ}\text{C}$ in the artificial system, with CVs of 2.83% and 2.40%, respectively. Mean pH was 7.15 ± 0.23 and 7.19 ± 0.17 , with CVs of 3.19% and 2.37%, respectively. Ammonia showed the most pronounced

difference between systems, with mean concentrations of 0.107 ± 0.063 mg/L (CV 59.03%) in self-sustaining tanks and 0.268 ± 0.225 mg/L (CV 83.90%) in artificial tanks. Total hardness averaged $1,771.03 \pm 229.87$ and $1,733.20 \pm 162.66$ mg/L as CaCO_3 , with CVs of 12.98% and 9.38%, respectively. The self-sustaining system therefore exhibited lower mean ammonia concentration and lower relative ammonia variability, whereas the artificial system showed slightly lower variability in temperature, pH and hardness. These findings indicate parameter-specific patterns of water-quality stability and suggest that biological components may contribute to nitrogenous-waste regulation in aquarium systems.

Keywords: self-sustaining aquarium; artificial aquarium; ornamental fish culture; water quality; ammonia; aquatic plants; biological filtration; temperature; sustainable aquaculture.

Introduction:

Aquarium and small-scale fish-rearing systems are confined aquatic environments in which physical, chemical and biological processes interact within a limited water volume. The accumulation of metabolic wastes, decomposition of organic matter and changes in pH and oxygen availability can alter the aquatic environment for cultured organisms. Water-quality management is therefore a central component of successful aquarium and aquaculture operations (Boyd, 1990; Boyd & Tucker, 1998).

Among the major water-quality variables, temperature and pH influence fish metabolism, physiological processes and microbial activity, whereas ammonia is an important indicator of nitrogenous-waste accumulation. Ammonia originates from fish metabolism and decomposition of organic matter and can be transformed through microbial nitrification into nitrite and subsequently nitrate. The establishment and functioning of microbial communities are therefore important in recirculating and biologically integrated aquatic systems (van Rijn, 1996; Preena et al., 2021; Wongkiew et al., 2017).

Conventional aquarium systems commonly use external interventions such as mechanical aeration, filtration and water replacement. Recirculating aquaculture systems and biological filters reduce dependence on continuous water replacement by facilitating water reuse and microbial processing of wastes (Gutierrez-Wing & Malone, 2006; Martins et al., 2010). Integrated fish-plant systems provide an additional biological pathway in which plants, microorganisms and fish interact through nutrient cycling (Rakocy et al., 2006; Somerville et al., 2014).

Self-sustaining aquarium systems represent a biologically oriented approach in which aquatic plants, substrate, microorganisms and cultured organisms function as an interconnected unit. Plants may assimilate dissolved nutrients and provide surfaces for microbial colonization, while biofilm-associated microorganisms participate in decomposition and nitrogen transformations (Srivastava et al., 2017; Kasozi et al., 2021). The resulting water-quality characteristics depend on the balance among biological loading, feeding, microbial activity and environmental conditions.

The present study was therefore undertaken to compare a self-sustaining aquarium system with an artificially maintained aquarium system under comparable laboratory conditions. Particular emphasis was placed on temporal variation in temperature, pH, ammonia and total hardness. The study was designed to evaluate whether incorporation of aquatic plants and biologically active components was associated with differences in water-quality stability.

Materials and Methods:

Experimental Design

The experiment was conducted in the Fisheries Laboratory, Department of Fisheries Science, Pandit Shambhu Nath Shukla University, Shahdol, Madhya Pradesh, India. The experimental period extended from 1 April to 25 June 2026, during which 15 observation periods were recorded. Eight aquaria were used: four self-sustaining tanks (SST-1 to SST-4) and four artificial tanks (AT-1 to AT-4). Both treatments were maintained in the same laboratory environment to minimize external environmental variation.

Experimental Treatments

Component	Self-sustaining system	Artificial system
Oxygenation	Aquatic plants and photosynthetic activity	Mechanical air pump/aerator
Waste processing	Biofilm and substrate-associated microorganisms	Mechanical filtration/filter cartridge
Feed source	Formulated feed plus naturally occurring biological matter	Formulated feed
Major process	Biological nutrient cycling and self-purification	Mechanical aeration and filtration

The self-sustaining tanks incorporated aquatic plants, primarily *Hydrilla*, *Ceratophyllum*, Monte Carlo and other aquatic plants, together with biologically active substrate. Plants were allowed to establish before experimental observations. The artificial tanks were maintained with mechanical aeration and a mechanical filter/filter cartridge. Fish in both treatments received formulated feed once daily, while the self-sustaining tanks additionally contained biological matter associated with plants and substrate.

Water-Quality Measurements

Temperature was measured in °C using a laboratory thermometer. pH was determined using an Aquacare commercial pH test kit. Ammonia was measured in mg/L using an Aquacare ammonia test kit according to the manufacturer's instructions. Total hardness was determined by an EDTA titration procedure and expressed as mg/L as CaCO₃. Samples were collected separately from each tank at the designated observation intervals without disturbing substrate or plant material.

Assessment of Variability and Stability

For each treatment, the observations were summarized using mean, standard deviation (SD), minimum, maximum and coefficient of variation (CV). CV was used as a measure of relative temporal variability; a

lower CV indicates lower relative fluctuation around the mean. A composite variability-based Stability Index (SI) was also calculated as a supplementary descriptive measure. The coefficient of variation was used as the primary measure of temporal variability.

Results:

Temperature and pH

Temperature remained within a relatively narrow range in both treatments. The self-sustaining system ranged from 25.5 to 28.8°C, while the artificial system ranged from 26.0 to 28.6°C. Mean temperature was $27.39 \pm 0.78^\circ\text{C}$ in self-sustaining tanks and $27.44 \pm 0.66^\circ\text{C}$ in artificial tanks. The corresponding CVs were 2.83% and 2.40%, respectively. Thus, the artificial system showed slightly lower relative temperature variability.

pH ranged from 6.4 to 8.5 in self-sustaining tanks and from 6.5 to 8.5 in artificial tanks. Mean pH was 7.15 ± 0.23 and 7.19 ± 0.17 , respectively, with CVs of 3.19% and 2.37%. The artificial system therefore showed slightly lower relative pH variability.

Ammonia

Ammonia displayed the largest relative variation among the measured parameters. Concentrations in self-sustaining tanks ranged from 0.01 to 0.36 mg/L, whereas

artificial tanks ranged from 0.06 to 1.48 mg/L. The mean concentration was 0.107 ± 0.063 mg/L in self-sustaining tanks compared with 0.268 ± 0.225 mg/L in artificial tanks. The CV was 59.03% in the self-sustaining system and 83.90% in the artificial system. The largest reported artificial-tank range occurred on 1 May 2026 (0.39–1.48 mg/L).

Total Hardness

Total hardness ranged from 1,320 to 2,840 mg/L as CaCO_3 in self-sustaining tanks and from 1,300 to 2,200 mg/L in artificial tanks. Mean hardness was $1,771.03 \pm 229.87$ mg/L as CaCO_3 in self-sustaining tanks and $1,733.20 \pm 162.66$ mg/L in artificial tanks. The CVs were 12.98% and 9.38%, respectively, indicating lower relative variability in the artificial treatment.

Comparative Summary

Parameter	Self-sustaining Mean $\pm$ SD	CV (%)	Artificial Mean $\pm$ SD	CV (%)	Lower CV
Temperature (°C)	27.39 ± 0.78	2.83	27.44 ± 0.66	2.40	Artificial
pH	7.15 ± 0.23	3.19	7.19 ± 0.17	2.37	Artificial
Ammonia (mg/L)	0.107 ± 0.063	59.03	0.268 ± 0.225	83.90	Self-sustaining
Total hardness (mg/L as CaCO_3)	$1,771.03 \pm 229.87$	12.98	$1,733.20 \pm 162.66$	9.38	Artificial

Discussion:

Both aquarium systems maintained relatively stable temperature and pH during the experimental period. The self-sustaining system recorded lower mean ammonia concentration (0.107 ± 0.063 mg/L) than the artificial system (0.268 ± 0.225 mg/L), with lower ammonia variability (CV: 59.03% vs. 83.90%). This pattern may be associated with the combined effects of aquatic plants, biologically active substrate and associated microorganisms involved in nutrient uptake and nitrogen transformation (Srivastava et al., 2017; Kasozi et al., 2021; Wongkiew et al., 2017).

In contrast, the artificial system showed slightly lower variability in temperature, pH and hardness. These differences indicate that the stability of aquarium systems can vary

according to the water-quality parameter considered. Biological components may contribute particularly to ammonia regulation, while mechanical aeration and filtration provide consistent physical and chemical control (Gutierrez-Wing & Malone, 2006; Martins et al., 2010).

Overall, the results demonstrate that both systems maintained consistent patterns for the measured water-quality parameters, with the self-sustaining system showing a distinct pattern of lower ammonia concentration and variability. Further studies including dissolved oxygen, nitrite, nitrate, microbial activity and plant nutrient uptake would help clarify the underlying mechanisms governing water-quality dynamics in biologically integrated aquarium systems.

Conclusion:

Under the conditions of the present experiment, both self-sustaining and artificial aquarium systems maintained relatively consistent temperature and pH. The self-sustaining system recorded a lower mean ammonia concentration and lower relative ammonia variability, while the artificial system showed slightly lower variability in temperature, pH and total hardness. These findings indicate that the two systems exhibited parameter-specific patterns of water-quality stability.

The incorporation of aquatic plants, biologically active substrate and associated microbial communities may contribute to nitrogenous-waste processing and support effective aquarium management. Overall, the findings highlight the potential of integrating biological components into aquarium systems for maintaining water-quality conditions, particularly with respect to ammonia regulation.

Conflict of interest:

The authors declare that they have no known conflict of interest related to this study.

References:

Boyd, C. E. (1990). *Water quality in ponds for aquaculture*. Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama.

Boyd, C. E., & Tucker, C. S. (1998). *Pond aquaculture water quality management*. Kluwer Academic Publishers, Boston, MA. <https://doi.org/10.1007/978-1-4615-5407-3>

van Rijn, J. (1996). The potential for integrated biological treatment systems in recirculating fish culture—A review. *Aquaculture*, 139(3–4), 181–201. [https://doi.org/10.1016/0044-8486\(95\)01151-X](https://doi.org/10.1016/0044-8486(95)01151-X)

Preena, P. G., Rejish Kumar, V. J., & Singh, I. S. B. (2021). Nitrification and denitrification in recirculating aquaculture systems: The processes and players. *Reviews in Aquaculture*, 13(4), 2053–2075. <https://doi.org/10.1111/raq.12558>

Gutierrez-Wing, M. T., & Malone, R. F. (2006). Biological filters in aquaculture: Trends and research directions for freshwater and marine applications. *Aquacultural Engineering*, 34(3), 163–171. <https://doi.org/10.1016/j.aquaeng.2005.08.003>

Martins, C. I. M., Eding, E. H., Verdegem, M. C. J., Heinsbroek, L. T. N., Schneider, O., Blancheton, J.-P., d'Orbcastel, E. R., & Verreth, J. A. J. (2010). New developments in recirculating aquaculture systems in Europe: A perspective on environmental sustainability. *Aquacultural Engineering*, 43(3), 83–93. <https://doi.org/10.1016/j.aquaeng.2010.09.002>

Rakocy, J. E., Masser, M. P., & Losordo, T. M. (2006). *Recirculating aquaculture tank production systems: Aquaponics—Integrating fish and plant culture*. SRAC Publication No. 454. Southern Regional Aquaculture Center.

Somerville, C., Cohen, M., Pantanella, E., Stankus, A., & Lovatelli, A. (2014). *Small-scale aquaponic food production: Integrated fish and plant farming*. FAO Fisheries and Aquaculture Technical Paper No. 589. Food and Agriculture Organization of the United Nations, Rome.

Srivastava, J. K., Chandra, H., Kalra, S. J. S., Mishra, P., Khan, H., & Yadav, P. (2017). Plant–microbe interaction in aquatic system and their role in the management of water quality: A review. *Applied Water Science*, 7, 1079–1090. <https://doi.org/10.1007/s13201-016-0415-2>

Kasozi, N., Abraham, B., Kaiser, H., & Wilhelmi, B. (2021). The complex microbiome in aquaponics: Significance of the bacterial ecosystem. *Annals of Microbiology*, 71, 1. <https://doi.org/10.1186/s13213-020-01613-5>

Wongkiew, S., Hu, Z., Chandran, K., Lee, J. W., & Khanal, S. K. (2017). Nitrogen transformations in aquaponic systems: A review. *Aquacultural Engineering*, 76, 9–19. <https://doi.org/10.1016/j.aquaeng.2017.01.004>