Review Article

Genetic Innovations, Global Trade Dynamics, Persistent Challenges and Future Prospects in Ornamental Fish Culture

Abstract

Ornamental fish culture is a specialized branch of aquaculture. This domain has emerged as a dedicated endeavor involving the breeding, care and the trade of visually captivating and often exotic fish species. This industry carries cultural, aesthetic and economic values, which makes substantial contributions to both local and global economies. Its evolution, traced from ancient civilizations to the widespread popularity of public aquariums in the 19th century and its 20th-century surge as a mainstream hobby, showcases the enduring human fascination with aquatic life. The integration of scientific research in the latter half of the 20th century marked a pivotal moment, transforming ornamental fishkeeping into a sophisticated discipline. This interdisciplinary approach, encompassing biology, genetics, and environmental sciences, has yielded comprehensive guidelines for optimal aquarium conditions. Genetic advancements, particularly in selective breeding have not only improved desirable traits but also played crucial role in conserving threatened and endangered species. This comprehensive review delves into the historical context, scientific progress, economic importance and ecological implications of ornamental fish culture. It also addresses industry challenges and proposes future research directions, underscoring the necessity of sustainable practices to ensure the well-being and longevity of ornamental fish.

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Keywords: Ornamental, genetic trait, selective breeding, global trade, aquaria, sustainable

1. Introduction

Ornamental fishes, due to their different and brilliant colors, shapes and behavior, are often referred to as living jewels and are kept in aquaria or garden pools for their beauty as well as entertainment. These species valued for their vibrant colors, distinctive patterns and

fascinating behaviors[1]. Ornamental fish culture involves not only the propagation of these species but also considerations of their well-being in captivity and sustainable practices to ensure the longevity of the industry. It holds cultural and aesthetic values with many societies incorporating ornamental fish into art, symbolism and religious practices [2]. The economic impact of the ornamental fish trade is substantial, contributing significantly to local and global economies. The industry encompasses a wide array of stakeholders from small-scale breeders to large commercial enterprises, creating employment opportunities and fostering economic growth [3].From a scientific point, it has evolved into a discipline that combines biology, genetics and environmental sciences. Researchers have been exploring complex genetics of these species to enhance desirable traits through selective breeding. The study of fish behavior and physiology in captivity has also expanded our understanding of aquatic life, providing insights that extend beyond the confines of ornamental fish culture [4]. The historical trajectory of ornamental fishkeeping is a captivating journey that intertwines human fascination with aquatic life and the evolving methods of capturing and displaying these captivating creatures. The roots of ornamental fishkeeping can be traced back to ancient civilizations where fish were initially kept for symbolic and cultural reasons [5]. In ancient Rome and Egypt fish were admired for their beauty and often featured prominently in murals and sculptures. The development of the first public aquariums such as the Crystal Palace Aquarium in London allowed people to marvel at exotic fish species from distant corners of the world. This period marked the democratization of ornamental fishkeeping as aquariums became more accessible to the general public [6]. The 20th century witnessed the popularization of ornamental fishkeeping as a widespread hobby. Innovations in filtration systems, aquarium design, and fishkeeping equipment made it easier for enthusiasts to create and maintain home aquariums [7]. This era also saw the rise of specialized fish breeders who focused on developing and enhancing the coloration and patterns of various fish species. As technological advancements continued, the latter half of the 20th century brought about significant changes in the industry. The advent of commercial breeding facilities coupled with improved transportation methods facilitated the global trade of ornamental fish. This globalization further expanded the diversity of available species and contributed to the economic growth of the industry [8].Ornamental fish breeding originated over a millennium ago in China with the domestication of goldfish, a freshwater species. The 1930s saw the commencement of marine trade in Sri Lanka, driven by the export of coral reefs for aquariums. Despite significant growth, the economic significance of the fish industry only emerged in the 1950s, experiencing a decline in production in the late 1990s [9]. Currently,

the ornamental fish market encompasses over 7000 aquatic species, with around 5000 being freshwater and 1800 marine species [10]. In contrast to marine varieties, the majority of freshwater specimens are now produced through captive breeding [11]. The ornamental fish industry involves more than 120 countries in import/export activities, primarily led by Asian and developing nations. Approximately 60% of ornamental fish production is contributed by these countries, resulting in a global trade value estimated between USD 15–30 billion annually [12].Genetic advancements have played a key role in shaping the discipline. Researchers and breeders employed sophisticated techniques to understand the genetic basis of traits like color, pattern and fin morphology [13]. This approach not only facilitated the creation of visually stunning fish varieties but also contributed to the conservation of endangered species by promoting controlled and sustainable breeding practices [14]. This interdisciplinary approach led to the development of comprehensive guidelines for optimal aquarium conditions like nutrition, health and water quality, ensuring the welfare of ornamental fish and promoting their longevity in captive condition[16].This review aims to explore historical context, scientific advancements, economic significance and ecological implications associated with ornamental fish culture.This review identifies challenges faced by the industry and outline future directions for research and practice.

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- There are good related references available, use them.

2. Diversity of Ornamental Fish

The taxonomy and diversity of ornamental fish represent a fascinating intersection of systematic categorization, molecular advancements and a rich array of cultivated varieties.

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Ornamental fish comprising diverse species which are systematically classified based on genetic and morphological characteristics that provide a structured framework for understanding their evolutionary relationships [17]. The Siamese Fighting Fish (*Betta splendens*) belongs to the family Osphronemidae show systematic organization that aids both scientific research and the management of the ornamental fish trade [18]. Recent strides in molecular taxonomy including DNA barcoding and phylogenetic analysis have revolutionized understanding of ornamental fish diversity. These techniques are useful in identifying hidden relationships and cryptic species, ensuring genetic diversity is preserved and supporting the long-term sustainability of the trade [19]. The Angelfish (*Pterophyllumscalare*) belonging to the Cichlidae family showcases various cultivated varieties resulting from selective breeding. From the iconic *Betta splendens*, renowned for its vibrant colors and territorial behavior to the elegant *Pterophyllumscalare* characterized by triangular bodies and elongated fins, each species brings its distinct attributes to the aquarium

landscape [20]. The Neon Tetra, with its iridescent blue and red stripes and the Clownfish are famous for their symbiotic relationship with sea anemones [21].Understanding the taxonomy and diversity of ornamental fish sets the stage for a comprehensive exploration of breeding techniques, environmental management and the broader economic and social impacts of this fascinating and continually evolving field.

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Species	Family	Notable Features
***Betta splendens* (Siamese Fighting Fish)**	Osphronemidae	Vibrant colors, flowing fins, and territorial behaviour
***Pterophyllumscalare* (Angelfish)**	Cichlidae	Triangular body, elongated dorsal and anal fins
***Paracheirodoninnesi* (Neon Tetra)**	Characidae	Iridescent blue and red stripes, schooling behaviour
***Amphiprionocellaris* (Clownfish)**	Pomacanthidae	Wide color variations, symbiotic relationship with anemones
***Danio rerio* (Zebrafish)**	Cyprinidae	Striking horizontal stripes, small size, active behaviour
***Poeciliareticulata* (Guppy)**	Poeciliidae	Colorful and diverse patterns, live-bearing reproduction
***Carassius auratus* (Goldfish)**	Cyprinidae	Various color varieties, distinctive body shapes
***Symphysodon spp.* (Discus)**	Cichlidae	Disc-shaped body, vibrant colors, intricate social behaviour
***Gasteropelecus spp.* (Freshwater Hatchetfish)**	Gasteropelecidae	Distinctive hatchet-shaped body, surface-dwelling behaviour
***Pseudotropheusdemasoni* (Demasoni Cichlid)**	Cichlidae	Blue and black coloration, social and territorial nature

Table 1: Common ornamental fish species with their family and contrasting features

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3. Advances in Ornamental Fish Breeding

3.1. Selective Breeding for Desirable Traits

Selective breeding in ornamental fish culture has advanced significantly through understanding of genetic principles and the heritability of traits. For instance, the *Bettasplendens* where selective breeding has resulted in a diverse range of color patterns and fin shapes. Studies in Betta genetics have identified specific genes responsible for the expression of colors such as red, blue and iridescence. The "Marble" trait characterized by a dynamic interplay of colors on the fish's body which has been traced back to genetic variations in pigment cells [22]. The Guppy (*Poeciliareticulata*) is another species that exemplifies the outcomes of selective breeding. Guppy breeders have focused on enhancing coloration, fin size and patterns through generations of careful selection. Scientific studies on guppy genetics have revealed the heritability of ornamental traits and the role of various genes in determining the expression of colors which ranges from vibrant hues to intricate patterns. Selective breeding has not only influenced aesthetics but also the behaviors [23]. In Cichlids, particularly the Discus (*Symphysodon spp*.), selective breeding has been employed to enhance the social behavior and compatibility of individuals within a group [24]. Studies have shown that certain genetic factors contribute to the development of harmonious social structures that reduce aggression and stress in captive environments [25]. Advancements in molecular genetics have provided a more precise understanding of the genetic basis of ornamental traits.Identification of specific color genes in ornamental fish has facilitated more targeted breeding programs. The knowledge gained from mapping the genomes of ornamental fish species contributes to the precision of selective breeding efforts ultimately minimizing unintended genetic consequences and promoting the stability of desired traits across generations.

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For example:
B.splendens

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3.2Artificial Reproduction Methods

Artificial reproduction methods have become pivotal in the domain of ornamental fish breeding that represent convergence of scientific innovation and conservation objectives. Hormone induced spawning, a well-established technique that deals with the precise administration of hormones to synchronize the reproductive cycles of fish [26]. Scientific studies, particularly in popular species such as the Angelfish (*Pterophyllumscalare*) have optimized hormone dosages and administration methods, exemplifying the meticulous

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refinement of protocols to enhance spawning success rates [27]. In vitro fertilization (IVF) has emerged as another cornerstone which allowing for the manual collection of eggs and sperm followed by fertilization outside the fish's body [28]. Genetic and endocrinological studies play a crucial role in the success of these artificial reproduction methods that provide insights into the hormonal regulation of reproductive processes and the genetic factors influencing gamete production. The Clownfish (*Amphiprionocellaris*) stands as an example where such studies have elucidated the hormonal control of sex change, a vital aspect for maintaining balanced populations in captivity [29]. Beyond economic considerations, the conservation implications of these methods are profound, offering a scientific avenue for the propagation of endangered species and contributing to genetic diversity within captive populations.Artificial reproduction methods underscore the dynamic play between scientific research and the practical applications that sustain the ornamental fish trade while concurrently supporting broader conservation initiatives.

3.3 Genetic Advancements in Enhancing Ornamental Traits

Ornamental fish breeding has recently made significant progress in understanding the genetic mechanisms that govern the diverse traits seen in different species like *Betta splendens*, Guppy (*Poeciliareticulata*) and Discus (*Symphysodon spp.*). In case of *Betta splendens* genetic research has pointed specific alleles and loci responsible for the striking color variations [30]. The MC1R gene plays a crucial role in determining red pigmentation while other genes contribute to the synthesis of iridescent hues. High-resolution molecular techniques such as genome-wide association studies (GWAS) have enabled the identification of genomic regions associated with specific color traits. These studies provide breeders with a molecular roadmap for precise selection based on the genetic markers associated with desired phenotypes [31].Male guppies exhibit a mosaic of complex and diverse coloration patterns, including blacks, oranges, and iridescent blues, which vary in number, shape, size, and position of spots. Female guppies show a strong mate choice preference for male color patterns, particularly for large spots and/or intensity of orange color. The genetic basis of color patterns in guppies involves various color loci, such as blue and golden, which play a decisive role in the formation of their color patterns. The observation of many diverse color patterns within the species represents a classic example of the genetic basis of color diversity. The genetic architecture of color patterns in guppies has a major effect on how these patterns evolve and diverge, and it involves a multivariate trait approach. The genetic basis of sex determination in guppies is also highly variable. Despite the wealth of knowledge about the

ecological importance of coloration in guppies, the specific genes and developmental pathways underlying their pigment pattern formation are still not fully understood [32].In Discus (*Symphysodon spp.*) breeding, genetic studies have identified genes related to melanin production and distribution. TYR and SILV genes are responsible for synthesis of melanin and pigment regulation respectively. The application of quantitative trait locus (QTL) mapping techniques has facilitated the identification of genomic regions associated with color pattern heritability that provide a molecular foundation for the selection of breeding pairs. The advent of high-throughput sequencing technologies has enabled the analysis of entire ornamental fish genomes [33]. The availability of complete genomic data allows researchers to explore not only specific genes associated with ornamental traits but also the broader genomic landscape governing these characteristics.

4. Environmental Management in Ornamental Fish Culture

4.1 Water Quality Optimization

Rigorous monitoring of aquatic parameters such as pH, temperature and nitrogenous compounds are imperative for maintaining the health of ornamental fish. Environmental management in ornamental fish culture, particularly water quality optimization, is a crucial aspect of sustainable aquaculture. The water quality of fisheries, including temperature, pH, nitrate, phosphate, and dissolved oxygen concentration, plays a significant role in the health and well-being of ornamental fish [34]. Maintaining good water quality is essential for the success of ornamental fish farming, as it directly impacts their growth, reproduction, and overall health. Several studies emphasize the importance of water quality in sustaining the ornamental fish business, highlighting the need for measures such as Good Aquaculture Practices (GAP) to ensure water quality and environmental sustainability [35]. Advancements in microbial feed additives and sensor technologies have been proposed to improve water quality and ensure the sustainable aquaculture of ornamental fish[36]. Therefore, effective environmental management, particularly in optimizing water quality, is fundamental to the long-term sustainability of ornamental fish culture.

4.2 Habitat Replication

Replication of natural habitats within aquariums is not merely an aesthetic pursuit but a scientifically guided practice rooted in a wealth of research findings. Scientific studies demonstrated that the inclusion of structured microenvironments such as live plants and hiding places significantly reduces stress levels in ornamental fish. These enriched

environments offer opportunities for natural behavioral activities, thereby contributing to the mental and physical well-being of the fish [37]. Lighting conditions play a critical role, it influence reproductive behavior of species like freshwater angelfish. Specific lighting conditions are demonstrated to stimulate courtship displays and improve reproductive outcomes. Scientifically guided adjustments of lighting for habitat are very essential for better results [38]. The dynamics of water flow greatly contribute to the creation of environments that mirror natural habitats, particularly for species adapted to flowing water [39]. Understanding temperature gradients enhances the thermoregulatory behaviors of ornamental fish, allowing them to move between warmer and cooler areas for optimal comfort and health [40]. In essence, the integration of these habitat replication practices isevidence to the thorough application of scientific knowledge, ensuring that aquariums not only showcase vibrant displays but also provide environments that closely align with the ecological and behavioral needs of these captivating aquatic species.

4.3 Disease Prevention and Control Strategies

In ornamental fish culture, disease prevention and control strategies are crucial for maintaining the health of the fish. Several methods and factors play a significant role in this aspect. A study by A.P. Lipton from the Central Marine Fisheries Research Institute in India emphasized the importance of preventing the entry of infectious agents to ornamental fish farm conditions [1]. The study also highlighted that several diseases of economic importance are recorded in ornamental fishes, and it summarized the common diseases, symptoms, and methods of inspection together with treatment protocols [41]. Furthermore, the Agriculture, Fisheries and Conservation Department of Hong Kong pointed out that fish diseases affect the survival and growth rates of fish under culture, leading to lower harvest and higher costs [42]. The document "Prevention and Treatment of Fish Diseases" emphasizes the importance of regular monitoring of fish health as an effective way to identify disease causes and take appropriate measures. Additionally, research on sustainable ornamental fish aquaculture has shown that the implication of microbial feed additives can contribute to disease prevention and control[43]. Various diseases affect ornamental fish and each require specific treatment strategy. Ichthyophthiriusmultifiliis (Ich) is a protozoan parasite which causes white cysts on the skin, gills and fins of Guppies, Tetras, Bettas, Angelfish and Goldfish. This can be treated by increasing water temperature and using anti-parasitic medications like formalin or copper. Columnaris Disease caused by Flavobacteriumcolumnare leads to lesions in Tetras, Guppies, Goldfish and Bettas. Treatment involves isolation and antibiotics like florfenicol or

sulfonamides. Dropsy is a symptom of an underlying disease that can be caused by poor water quality, stress, or other diseases. It is characterized by abdominal swelling and can affect Goldfish, Guppies, Betta, Tetras, and Angelfish. Treatment involves addressing the underlying causes through antibiotics or water condition improvements. Velvet Disease (Oodinium) is a parasitic infection that causes colored dust on Tetras, Guppies, Angelfish, Discus, and Goldfish. It is treated by quarantine and copper-based medications. Hexamita, a protozoan parasite causing gastrointestinal issues, affects Cichlids, Discus, Angelfish, Guppies, and Tetras, and is treated with anti-protozoal medications. Lymphocystis, a viral infection causing wart-like growths, affects Goldfish, Guppies, Angelfish, Tetras and Discus, with no specific treatment but recovery aided by good water quality and stress reduction. Spring Viremia of Carp (SVC), a viral disease in Koi, Goldfish, Rosy Barb and Tetras, has no specific treatment, prevention involves strict biosecurity measures and the destruction of infected fish [44]. Some of the common ornamental fish diseases are given in table 2.

Disease	**Agent**	**Symptoms**	**Ornamental fish affected**	**Treatment strategies**	**Reference**
White spot disease	*Ichthyophthiriu smultifiliis*	white cysts on the skin, gills and fins.	Guppies, Tetras, Bettas, Angelfish and Goldfish	Use anti-parasitic drugs, like formalin or copper.	[45]
Fin Rot	*Pseudomonas fluorescens*	deterioration of fins.	Guppies, Tetras, Betta, Goldfish	Administer antibiotic containing tetracycline.	[46]
Columnaris Disease	*Flavobacteriu mcolumnare*	Lesions all over the body	Tetras, Guppies, Goldfish, Bettas	Administer antibiotic treatments like florfenicol or sulphonamides	[47]
Dropsy	*Aeromonashyd rophila*	Abdominal swelling	Goldfish, Guppies, Betta, Tetras, Angelfish	Broad spectrum antibiotic specifically formulated for gram-negative bacteria	[48]
Velvet Disease	*Oödiniumpilul aris*	Lethargy, Loss of appetite and weight, discoloration	Tetras, Danios, Angelfish, Discus, Goldfish	Add aquarium salt and treat with MardelCoppersafe for ten days	[49]

Gill Flukes	*Dactylogyrus*	Rapid Gill Movement, Color Change	Koi and goldfish	Praziquantel liquid, Formalin and Malachite Green	[50]
Hexamita	*Octomitus,Spironucleus*	large quantities of white, yellow mucous	Discus fish, Cichlids, Oscars, Silver dollar	Metronidazole andEpsom salt	[51]
Lymphocystis	*Iridovirus*	small size irregular, nodular, wart-like growths on fins and skin	Gobies, snook butterflyfish, clownfish and gouramies	potassium permanganate (100 mg/L or higher), formalin (2000 mg/L or higher)	[52]

Table 2: Common Ornamental Fish Diseases, Causative Agents, Symptoms, Affected Fish Species, and Treatment Strategies

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5. Globalornamental fish trade

In 2021, ornamental fish emerged as the world's 3120th most traded product, with a total trade value of $392 million, accounting for 0.0019% of the global trade. The exports of ornamental fish grew by 18.6% between 2020 and 2021, increasing from $330 million to $392 million. The top exporters of ornamental fish in 2021 were Japan ($44.9 million), Singapore ($41.7 million), Indonesia ($40.7 million), the Netherlands ($31.5 million), and Sri Lanka ($23.1 million). The top importers were the United States ($74.8 million), Germany ($31.1 million), France ($25.5 million), the United Kingdom ($24.4 million), and China ($19.1 million). In 2018, the average tariff for ornamental fish was 11.3%, making it the 1888th lowest tariff using the HS6 product classification [53]. Ornamental fish ranks3954th in the Product Complexity Index (PCI) [54]. Figure 1 and 2 represent the top importer and exporter countries in ornamental fish culture.India's share of the global ornamental fish export is around 0.4%, and the domestic ornamental fish trade is estimated to be about Rs. 500 crore, with an export trade of Rs. 8.40 crore in 2017-18, growing at an average annual rate of 11-12%. The industry is supported by the Pradhan Mantri Matsya Sampada Yojana (PMMSY), which has an allocation of Rs. 576 crores to catalyze its growth [55]. Despite this potential, India still remains a marginal player in the global ornamental fish trade. India has great potentials in Ornamental fish production due to the rich biodiversity of species,

favourable climatic conditions and availability of cheap labour. Kerala, Tamil Nadu and West Bengal are mainly involved in practicing ornamental fish farming in India [56].

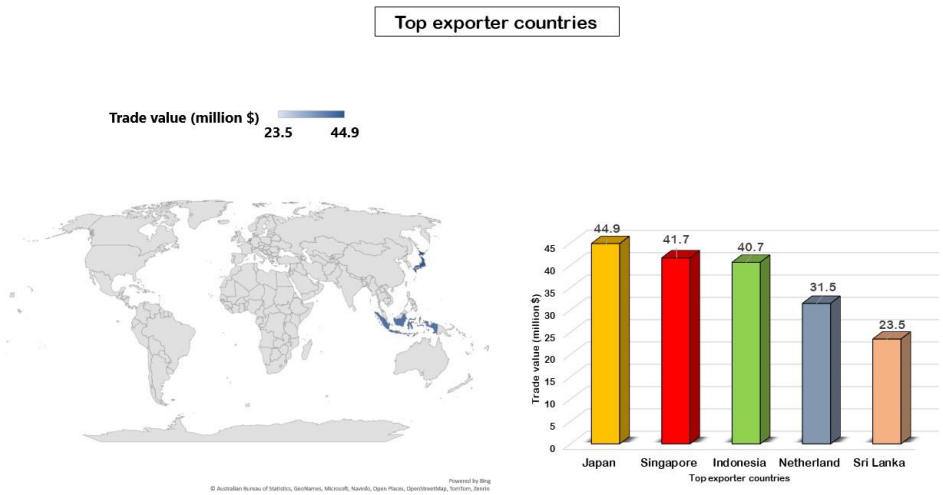

Figure 1: Graph represents top exporter of ornamental fish worldwide. Japan is leading exporter of ornamental fish in global trade

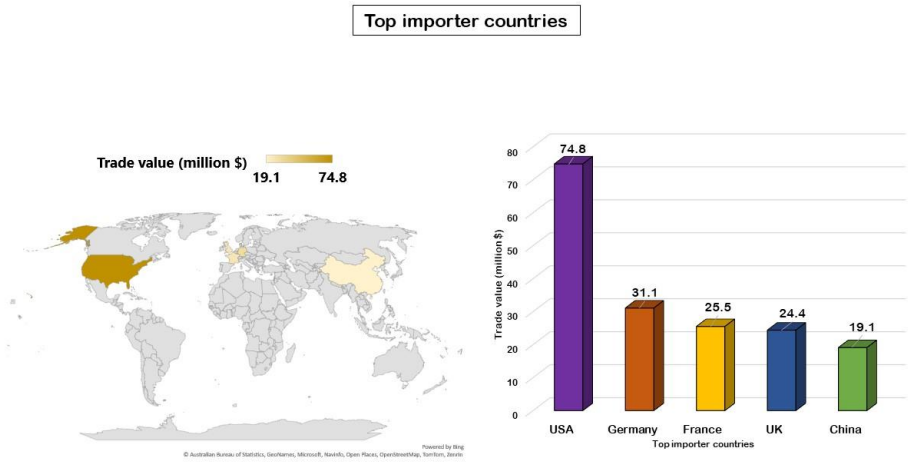

Figure 2: Graphrepresents top importer of ornamental fish worldwide. Data shows USA is leading importer of ornamental fish in globally

6. Strategies for enhancing ornamental fish industry in India

The ornamental fish industry in India holds great promise for expansion, with the country currently contributing approximately 1% of the global ornamental fish trade, exporting around 54 tons of ornamental fish. To further develop and grow this industry, it is essential to assess the potential of ornamental fishes for rational utilization and export, as well as to improve the production practices, which currently rely on low-input and low-output concepts [57]. This improvement can be achieved through intensive training programs, support for fish breeders and the promotion of modern breeding techniques. Additionally, the government can increase its growth to several folds by providing financial assistance, infrastructure, instrumentations and marketing support to the ornamental fish industry. By implementing these strategies, India can enhance its position in the global market of ornamental fish trade and further boost the economic importance of this sector. India's share in the global ornamental fish trade is 0.4%, and it is ranked 31st in exporting countries, indicating significant potential for growth and improvement in this industry [58].

7. Challenges in Ornamental Fish Culture

The ornamental fish culture industry faces several challenges that need to be addressed for sustainable growth. One of the primary challenges is the overexploitation of wild fish, which make up the majority of the trade, with less than 10% coming from hatchery production[59]. This overexploitation raises concerns about the impact on native species and the need for gender equality in the supply chain. Developing nations, particularly in Asia, are significant players in the sector, and there is a need to ensure that the industry does not negatively impact the environment and local communities. The market for ornamental fish is dominated by hobbyists, and there are implications for sustainable aquaculture, such as the use of microbial feed additives [60]. Research is being conducted to address some of these challenges, including ornamental fish behavior analysis using IoT and ML approaches [61]. Additionally, there is a need for sustainable ornamental fishing practices, breeding practices for aquarium

fish, and the development of entrepreneurship in the rural sector for indigenous ornamental fish production. The global ornamental fish market was valued at USD 9509.4 million in 2019, with an expected CAGR of 6.2% during 2021-2026, and is poised for significant growth between 2023 and 2029. However, overexploitation by the aquarium fish trade, habitat degradation and destruction, alien species introductions, pernicious tourism, and pollution are principal threats to marine biodiversity[62]. To address these challenges, research is needed to identify susceptible species and develop sustainable practices for the industry.

8. Future perspectives and research gaps

The field of ornamental fish culture has experienced significant advancements, but there are still research gaps that need to be explored. Some of the future perspectives and potential areas of focus include sustainable breeding practices to conserve species and minimize environmental impact, exploring the ecological impact of the ornamental fish trade on aquatic ecosystems, and addressing the constraints affecting ornamental fish production, such as high production costs and skill gaps [63]. Additionally, research could focus on health and disease management, including developing vaccines, diagnostics, and treatments for ornamental fish, and understanding the genetic diversity of ornamental fish and developing selective breeding techniques to enhance desirable traits without compromising overall genetic health. Furthermore, analyzing market trends and consumer preferences is crucial for guiding sustainable production practices and considering socio-economic aspects, ensuring that the industry remains viable and relevant in the future. Integrating technology, such as gene editing, in ornamental fish breeding could lead to more efficient and sustainable production processes and developing effective regulatory frameworks that balance industry growth with conservation and ethnic considerations are essential [64]. Addressing these aspects can contribute to the industry's sustainability, biodiversity conservation, and the well-being of captive fish.

Comment [I12]: The results are very poorly presented.It must be rewritten and otherwise it is not acceptable.

9. Discussion

Ornamental fish culture is a rapidly growing industry worldwide, generating billions of dollars annually. This review article discusses various aspects of ornamental fish culture, including taxonomy and diversity, breeding, artificial reproduction methods, genetic advancements, environmental management, water quality optimization, habitat replication, disease prevention and control strategies, global trade, strategies for enhancing the industry in

India, challenges, and future perspectives. Taxonomy and biogeography of ornamental fish are essential for their conservation and management. DNA barcoding is a useful tool for identifying ornamental fish species. Ornamental fish are diverse and come from various families, including Cichlidae, Cyprinidae, Characidae, and Poeciliidae. Selective breeding for desirable traits is a common practice in ornamental fish culture. Advances in breeding techniques have led to the development of new strains and varieties of ornamental fish. Breeding programs have been successful in producing fish with desirable traits such as color, shape, and size. Artificial reproduction methods such as hormone-induced spawning and stripping have been developed for many ornamental fish species. These methods have made it possible to produce large numbers of fish with desirable traits in a short period. Genetic advancements have been made in enhancing ornamental traits such as color, shape, and size. Genetic engineering techniques such as transgenesis and gene editing have been used to produce fish with desirable traits. However, the use of genetic engineering techniques in ornamental fish culture is still in its infancy, and more research is needed to assess the environmental impact of these techniques. Environmental management is essential for the successful culture of ornamental fish. Water quality optimization, habitat replication, and disease prevention and control strategies are critical components of environmental management. Water quality optimization is essential for the health and growth of ornamental fish. Proper filtration, aeration, and maintenance of water parameters such as temperature, pH, and dissolved oxygen are critical for maintaining optimal water quality. Habitat replication is essential for the successful culture of ornamental fish. Replicating the natural habitat of the fish can help reduce stress and improve their health and growth. Disease prevention and control strategies are essential for the successful culture of ornamental fish. Proper quarantine, hygiene, and disease monitoring can help prevent the spread of diseases in fish farms. The global trade in ornamental fish is a rapidly growing industry, generating billions of dollars annually. The industry involves most tropical and subtropical regions, with Asia being the largest producer and exporter of ornamental fish. The trade is regulated by international and national laws to prevent the spread of diseases and protect endangered species. India possesses a rich diversity of ornamental fish, with over 195 species found in inland and marine waters. However, most of these species are collected from the wild due to a lack of species-specific culture or breeding. Strategies for enhancing the ornamental fish industry in India include the development of breeding programs, the promotion of sustainable aquaculture practices, and the establishment of a regulatory framework for the trade of ornamental fish. Ornamental fish culture faces several challenges, including disease

outbreaks, environmental degradation, and the illegal trade of endangered species. The lack of proper infrastructure, technical knowledge, and funding also poses a significant challenge to the development of the industry. The future of ornamental fish culture lies in the development of sustainable aquaculture practices, the use of genetic engineering techniques to produce fish with desirable traits, and the establishment of a regulatory framework for the trade of ornamental fish. Research gaps include the development of new breeding techniques, the identification of new species, and the assessment of the environmental impact of ornamental fish culture.

Comment [I13]: Correct according to the results.

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