

Ornamental Fish Industry: Emerging Challenges of Antimicrobial Resistance (AMR) and Possible Remedies

Akansha Tiwari^{1*}, Pravesh Kumar² and Roshan Kumar Ram³

¹M.F.Sc. Student, Department of Aquaculture, College of Fisheries, RPCAU, Muzaffarpur, Bihar

²Assistant Professor, Department of Aquaculture, College of Fisheries, RPCAU, Muzaffarpur, Bihar

³Assistant Professor, Department of Fisheries Resource Management, College of Fisheries, RPCAU, Muzaffarpur, Bihar

Corresponding Author

Akansha Tiwari

Email: akankshatiwari678@gmail.com



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ABSTRACT

A multimillion-dollar business, ornamental fish are popular in about 125 different nations across the globe. It helps the nations get foreign exchange in addition to beauty and tranquility. A significant portion of the world's aquaculture is devoted to the production and trading of ornamental fish, which enhance the aesthetic value of different fish species. However, it faces significant challenges from bacterial, fungal, and parasitic diseases that can lead to substantial economic losses by compromising the fish health. To combat this problem, farmers have increased their dependency on antibiotics, leading to the problem of antimicrobial resistance (AMR). Unlike the edible fish industry, the ornamental fish industry does not have strict regulations against the use of antimicrobials leading to increasing reports of AMR in the ornamental industry. This article provides an overview of the ornamental fish industry, highlighting the use of antimicrobials, the challenges posed by antimicrobial resistance, and potential solutions to address these issues.

INTRODUCTION

Ornamental fishes are getting very popular among people as both, a sign of good luck and an easily handled pet for pet lovers. It is a growing industry with an estimated value of about US \$ 5 billion. The contribution of India to it is only about 1%, which suggests that India has a lot to explore in this sector. More than 100 countries are the suppliers of ornamental fish majorly being Southeast Asian countries such as Malaysia and Thailand whereas the major importer is the USA. The most common and economically important freshwater ornamental fishes are goldfish (*Carassius auratus*), koi carp (*Cyprinus carpio koi*), red swordtail (*Xiphophorus hellerii*), and Zebrafish (*Danio rerio*). As an upcoming sector with too much potential to fuelling the demand for healthy and disease-free fish. The main problem faced by producers in ornamental fish culture is a disease outbreak resulting in mass mortality and causing an economic loss for the producers. These diseases can be caused due to many factors such as unhygienic care, and poor feed quality. To prevent and treat these outbreaks administration of antimicrobials has become very common. However, the over and unregulated use of these antimicrobial drugs without proper diagnostics can contribute to the development of antimicrobial-resistant strain of pathogens. That will make the infection more difficult to treat as it reduces the effectiveness of the antimicrobial and causes environmental hazards. Many of these common antimicrobial resistance isolates are found to be potentially zoonotic (Rose *et al.*, 2013), so if they are not treated properly can affect other fish species as well humans. So, the professionals working in this industry need to stay updated about the guidelines and recommendations provided by the regulatory authorities and industry experts.

Overview of ornamental fish industry

The ornamental fish industry comprises the breeding, production, and trading. According to the report of Grand View Research 2017-21, the global market of the ornamental fish industry is USD 5.88 billion in 2022 and is expected to have a compound annual growth rate (CAGR) of 8.5% from 2023 to 2030. The export and import values of live ornamental fish are given in Fig. 1 and Fig. 2 respectively. Nowadays fish as pets is started to become very popular hobby, a sign of luck and prosperity, and due to its health benefits like reduction in stress and anxiety. During global covid pandemic only U.K households acquires 3.2 million fish as pets. In terms of revenue generation, the freshwater ornamental fish market has dominated the industry with a 51.6% share in 2022. The most common tropical freshwater fishes domesticated are goldfish, tetras, guppy, mollie, and betta fish.

Marine ornamental fish industry is projected to register a CAGR of 9.5% from 2023 to 2030. It is mostly divided into 2 subcategories i.e., reef and fish-only aquariums. The most common marine ornamental fishes kept as pets are angel fish, clown fish, butterfly fish, etc. Some of the big names in the global ornamental fish industry are Aqua-Nautic specialist Pte Ltd., BioAquatix, LiveAquaria, Oasis Fish Farm, Qian Hu Corporation Limited, Algae Barn LLC, etc. In November 2021, Imperial Tropicals partnered with Hikari to develop a brand of feed that is suitable for all types of ornamental fish, wild-caught or cultured. India is rich when it comes to the diversity in ornamental fishes, we have over 195 indigenous varieties reported from the northeast and western ghats, out of which about 155 have ornamental values. Also, there are about 400 species reported from marine ecosystems. Ornamental fish trade in India mostly deals with freshwater fishes which

make up 90% of the total share out of which about 98% is cultured and 2% is wild-caught. According to a NFDB report on ornamental fisheries in India, when it comes to marine ornamental fishes, they share about 10% of the total market, most of it is wild caught with about 2% culture fisheries.

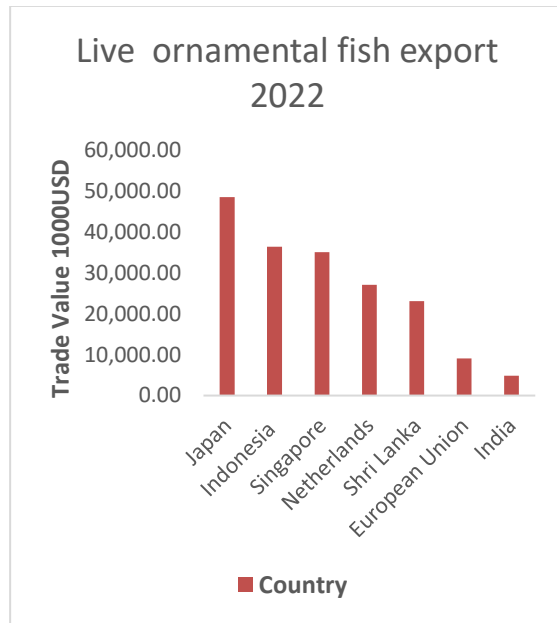


Fig. 1: Live ornamental fish export value 2022 (WITS, 2022)

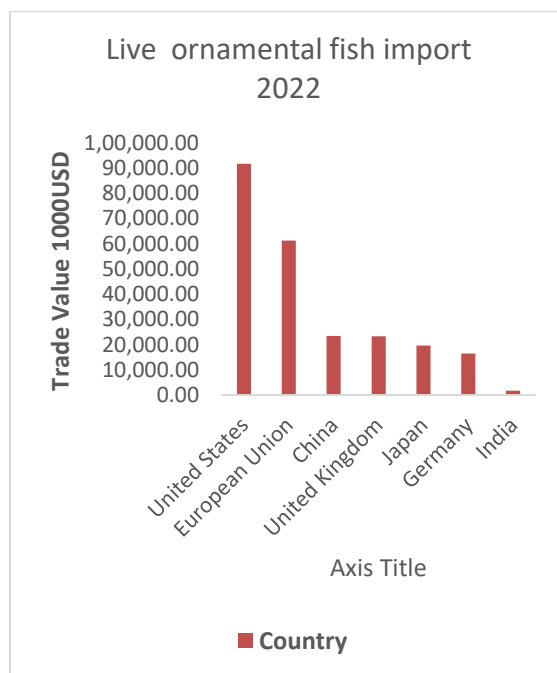


Fig. 2: Live ornamental fish import value 2022 (WITS, 2022)

Ornamental fish health management

As much as ornamental fishes are beautiful to look at, they are also very delicate in nature. Slight changes in their environment can put them to stress for example, poor water and feed quality, temperature fluctuation, DO, etc. fish health management program is outlined with an emphasis on 4 factors: fish, water, container, and nutrition (Francis-Floyd *et al.*, 1990). The disease can be shown by some common observable symptoms such as loss of colour, loss of appetite, sluggishness and abnormal swimming behaviour, etc. One deal with the situation using two methods, either prevent the disease from infecting the cultured fish or treat the disease after its infection. Infectious diseases are the result of interaction with a susceptible host, pathogen, and the environment which can provide a suitable medium that increases the chances of infection. Prevention of the disease can be done by being cautious during the cultural process for example by water quality management, proper filtration, proper oxygenation of the water, and water exchange. Nutrition also plays a crucial role in maintaining health. A balanced feed with appropriate feeding frequency can have positive effects on their health and immune system. Stress management and regular monitoring in the form of physical appearance, general behaviour, and appetite are also vital steps for the prevention of the disease.

Common diseases in the ornamental fish industry

Most of the pathogenic bacteria are gram-negative bacteria, e.g., *Aeromonas*, *Flavobacterium columnare*, *Vibrio*, and *Pseudomonas*. The other major group of bacteria that causes the fish disease is *Streptococcus* (Pandey, 2014). The most common microbial disease in ornamental fishes includes Aeromoniasis or Ulcer which is caused by *Aeromonas sp.*, fin and tail rot

disease which is caused by either *Aeromonas sp.* or *Pseudomonas sp.*, columnaris disease which is caused by *Flavobacterium columnare*, Mycobacteriosis which is caused due to *Mycobacterium fortuitum*, Dropsy which is caused by *Aeromonas hydrophila*, Saprolegniasis or Cotton wool disease by *Saprolegnia parasitica*, and Bacterial gill disease which is caused by *Myxobacteria sp.* The most observed viral disease of tropical fish is called lymphocystis disease. This disease is caused by an iridovirus which infects connective tissue cells of the fish. Apart from that other viral diseases are Koi Herpes Virus Disease (KHVD) caused by Koi Herpes Virus and Fish pox caused by herpes virus. One of the most common parasitic diseases is “Ich” disease or “white spot disease” caused by *Ichthyophthirius multifiliis*. All the diseases along with some common clinical signs, have some characteristic signs which can help in determination of the type of microbial infection. The prevention and treatment of these diseases are very important to minimize ecological and economic loss. The impact of these diseases can be mitigated by using proper quarantine protocols, regular sampling, and maintaining optimal water quality parameters. The treatment of the infected fish with appropriate medication and maintaining the environmental factors to the optimal condition can reduce the spread of the disease among the population.

Antimicrobials and their use in ornamental fish

Antimicrobials play a very crucial role in aquarium health management by being part of quarantine protocols, prevention, and treatment of the disease. The most common antibiotics used are penicillin, oxytetracycline, erythromycin, chloramphenicol, and aminoglycosides. Among these the most used drugs in the ornamental fish industry are chloramphenicol, followed by oxytetracycline and erythromycin. Some other antibacterials

are nitrofurans, quinolones, and sulpha drugs (Pandey, 2014). The selection of a drug and its proper dosage is very important for the proper administration of antibiotics. These are studied based on 2 things; firstly, the pharmacokinetics of the drugs, and secondly, the percentage active ingredient of the product (Yanong, 2003). After choosing the right dosage the route of administration of the drugs is selected, which can majorly be of 3 types; feed administration, via injection, and bath treatment (Yanong, 2003). These antimicrobials and disinfectants are only effective when given before or at the preliminary stages of infection. Erythromycin and penicillin are mostly effective against gram-positive bacteria for example streptococcus species mainly given by injection or feed. Oxytetracycline is a broad-spectrum antibiotic and can be administered as bath treatment and feed treatment. They are not very effective in hard water as Calcium and magnesium ions can bind with the compound molecule and make it inactive. Aminoglycosides including neomycin are effective against gram-negative bacteria when administered through injection as they are not very effective with external or oral treatments. Sulpha drugs are also broad-spectrum drugs but some of the compounds are not very effective as before because of the antimicrobial resistance developed in the species. They are mainly mixed with feed for administration. Nitrofurans are banned by FDA on food fishes but are commonly used in ornamental fishes with proper dosing they are administered through bath treatments (Pandey, 2014).

Some of the FDA-approved aquaculture drugs are Chloramine-T, Formalin, Oxytetracycline hydrochloride in immersion treatment, Florfenicol, Oxytetracycline dihydrate, Sulfadimethoxine, Sulfamerazine. However, it is also important that antimicrobials are used responsibly to avoid antimicrobial resistance.

The ornamental fish sector must follow recommended dosing procedures, adhere to prescription recommendations, and, if necessary, consult a veterinarian. This maintains the antimicrobials' potency and ensures that they continue to be beneficial in promoting the health and welfare of ornamental fish.

Antimicrobial-resistant (AMR) in ornamental fish

Antimicrobial-resistant bacteria result from indiscriminate use of antimicrobials, resulting in antibiotic selection pressure and proliferation of the said bacteria. It is a global concern that affects various sectors including human, agriculture, veterinary, and aquaculture. The main factors that are responsible for the emergence of antimicrobial resistance are overuse or misuse of antimicrobials, inadequate infection prevention and its control, and environmental factors such as the discharge of antimicrobial residue directly or indirectly to the aquatic ecosystem or through the food chain. This is reducing the treatment options as the effectiveness of currently available treatment options is diminishing, it is also increasing the burden on the healthcare system, and it is hurting animal health and welfare. In a recent study of antimicrobial susceptibility in 64 strains of aeromonads was tested and found that it showed resistance for most major antibiotics (Saengsitthisak *et al.*, 2020). Another study was done on ornamental fish in Hong Kong and concluded that high level of antibiotic resistance of *Aeromonas* and *Pseudomonas* sp. against tetracycline and oxytetracycline (Au-Yeung, 2022). Although the use of antimicrobials is inevitable in health industries the need to keep the dosage in check has never been more important. There is also a need to improve infection prevention and control methods, research and development in this area, and monitor the spread of AMR.

Alternatives for Antimicrobials

Global expansion and intensification of aquaculture in recent decades have led to an exponential increase in aquatic disease outbreaks. The most common treatment to which includes antimicrobials. However, with the recent increase in Antimicrobial Resistance (AMR) in fish alternatives to these antimicrobials are being promoted. Some of them are as listed below:

- **Vaccines** – They are made from the attenuated or inactivated form of pathogenic microorganisms or a small protein or DNA of pathogen to prevent infectious disease (Siegrist, 2018). Vaccines such as KV-3 used as immersion injections against Koi Herpes Virus (KHV) are available for commercial use. Recently, several RNA and DNA-encoding vaccines have been developed which are found to be relatively easy to manufacture and are safer to administer (Ma *et al.*, 2019). For salmonids having Infectious haematopoietic necrosis (IHN), DNA vaccine namely Apex-IHN has been introduced. Similar steps need to be taken in case of ornamental species.
- **Bacteriophages** – These are bacterial viruses that invade bacterial cells and cause disruption in bacterial metabolism causing bacterial lysis. They are naturally occurring organisms as well as highly selective for their bacterial strains. Moreover, they do not disrupt the beneficial microbiota within the aquatic environment, maintaining a balanced ecosystem. They can be given through water and feed. Some of the phages against specific bacterial hosts of the genus *Vibrio*, *Pseudomonas*, *Aeromonas* etc. have already been isolated and used in the edible fish industry.
- **Quorum Quenching** – It is referred to all the process that are involved in disturbing

bacterial communication (Quorum Sensing) (Dong *et al.*, 2001). It significantly reduces the risk of developing antibiotic resistance by disrupting this communication process. It involves a wide range of phenomena and mechanisms, with a diverse array of molecular agents, such as enzymes and chemical compounds, that operate through various modes of action, including QS-signal degradation, competitive inhibition, and others (Grandclément *et al.*, 2016). In the ornamental fish industry, bacterial pathogens such as *Aeromonas*, *Vibrio*, and *Pseudomonas* utilize quorum sensing to cause infections, form biofilms, and release toxins, which can result in conditions like fin rot, ulcerative diseases, and septicemia. Quorum-quenching agents, including small molecules, enzymes, or microbial compounds, disrupt these QS signals, thereby reducing bacterial virulence and preventing the onset of disease.

- **Medicinal plants** – It may include herbs, seaweeds, herbal extracts, and commercial plant-derived products (Van Hai, 2015). It gained significant interest due to their natural, eco-friendly properties. Medicinal plants contain a wide range of bioactive compounds, such as alkaloids, flavonoids, tannins, and essential oils, which possess antimicrobial, anti-inflammatory, and immunostimulatory properties. They can be incorporated into the diet as well as given through water treatment. An example of a medicinal plant used as an antimicrobial is *Azadirachta indica* (neem) that possess strong antibacterial properties against pathogens like *Aeromonas hydrophila* and *Vibrio spp.* Similarly, *Ocimum sanctum* (basil) is known for its antimicrobial and antioxidant properties, and studies have demonstrated its effectiveness in reducing infections caused by *Pseudomonas aeruginosa*.

Guidelines for the use of Antimicrobials

Government guidelines on the use of antimicrobials in the ornamental fish industry are very important to promote responsible and sustainable practices that can minimize the emergence of antimicrobial-resistant bacteria. Recently due to the increase in antimicrobial resistance bacteria, there has been global interest in controlling the risk by the establishment of regulatory guidelines. In China, regulations on antibiotic use only apply to food fishes (Au-Yeung, 2022), this resulted in the unregulated administration of antimicrobials in ornamental fishes. Some international organizations that produced recommendations on the responsible use of antimicrobials include; the Global Principles for the Containment of Antimicrobial Resistance in Animals Intended for Food published by the World Health Organization, the International Standards on Antimicrobial Resistance produced by the World Organisation for Animal Health, the Code of Practice to Minimize and Contain Antimicrobial Resistance (CAC/RCP 61-2005) and the Code of Practice for Fish and Fishery Products (Section 6 Aquaculture Production) (CAC/RCP 52-2003), published by the Codex Alimentarius Commission.

CONCLUSION

From this discussion, it can be concluded that the use of antimicrobials is inevitable. But the need to stop it from overuse and the emergence of antimicrobial-resistant bacteria needs to be regulated and kept in check. To achieve that goal the need to spread awareness about the negative impacts of these antimicrobials has become of utmost importance. As much as the government has taken steps towards the regulation of their use in food fishes. The regulation of their use in the ornamental fish industry is also needed. Animal health institute has already taken step towards developing new products to prevent

and treat bacterial infection rather than depending on antibiotics. In other words, if monitored carefully antimicrobials are a boon for the ornamental fish industry.

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