

## One Health Approach to Controlling Antimicrobial Resistance in Aquaculture

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### Abstract

Antimicrobial resistance (AMR) in aquaculture has emerged as a critical global challenge driven by the excessive and often unregulated use of antibiotics in fish and shrimp farming, fostering resistant pathogens that threaten animal productivity, environmental integrity, and human health. This article explores how antibiotic residues and resistant bacteria circulate through aquatic ecosystems, seafood chains, and clinical settings, reinforcing a continuous AMR cycle. It emphasizes the One Health approach as an integrated solution that unites human, animal, and environmental sectors to promote responsible antibiotic stewardship, genomic surveillance, farm-level biosecurity, vaccination, probiotics, and sustainable management practices. Strengthening policy enforcement, farmer education, and environmental protection is essential to reducing antibiotic dependency. Coordinated multisectoral action is crucial to safeguard antimicrobial effectiveness, ensure food safety, and secure sustainable aquaculture for future generations.

**Keywords:** Antimicrobial resistance, One Health, Aquaculture, Antibiotic stewardship

### Introduction

Producing more than half of the world's seafood and providing for millions of livelihoods, aquaculture is a vital component of global food security, particularly in Asia, where extensive fish and shrimp farming propels economic expansion. However, this growth has a price: the widespread overuse of antibiotics to treat bacterial

illnesses like vibriosis has accelerated antimicrobial resistance (AMR), giving rise to superbugs like multidrug-resistant *Vibrio* and *Aeromonas* that avoid treatment and spread to human health through polluted water, seafood, and agricultural wastewater. With resistant strains already found in clinical cases connected to fish consumption, the problem poses a threat to aquaculture productivity and public safety in places like India, where district-level surveillance shows increasing resistance amid climate-stressed ponds.

By combining human, animal, and environmental health, the One Health approach provides a cohesive strategy to break the vicious cycle of AMR in aquaculture. In contrast to isolated initiatives, it encourages cooperation between farmers, veterinarians, doctors, and regulators. It does this by using genomic surveillance (e.g., WGS with tools like ResFinder) to track resistance genes from ponds to plates and by supporting alternatives to antibiotics, such as probiotics, vaccines, and phage therapy. There are numerous success stories: Bangladesh's farmer training pilots reduced usage by fostering biosecurity, while Norway reduced the use of antibiotics on salmon farms by 99% through monitoring and vaccination. The urgency is highlighted by India's post-2025 antimicrobial prohibitions, which position One Health as essential to sustainable practices that protect fish health, ecosystems, and future generations (Milijasevic et.al., 2024).

### **Antimicrobial Resistance from The One Health Approach**

Since illnesses cannot be treated with existing antimicrobials (the WHO's 2019 report identified only 32 in development, with six innovative), the rapid global spread of multidrug-resistant bacteria poses a serious challenge, taxing health systems and increasing mortality. New medications will soon lose their effectiveness if misuse is not stopped, and AMR causes financial harm through prolonged hospital stays and lost productivity due to things like excessive use of antibiotics, inadequate sanitation, loose infection controls, restricted access to vaccines, low awareness, and regulatory errors. The WHO, FAO, and OIE's Global Action Plan encourages standardized monitoring of antimicrobial use, allowing correlation studies, spread tracking, and intervention assessments to protect ecosystems and public health. AMR, being a One Health crisis, necessitates integrated surveillance across humans, animals, and environments (Velazquez et al., 2022).

### **Aquaculture and Antibiotics: Where Things Go Wrong**

#### **Reasons for Antibiotic Use**

Antibiotics are frequently used in aquaculture for prophylaxis to prevent disease outbreaks in crowded ponds and cages, therapeutic treatment of infections including those caused by *Vibrio* and *Aeromonas* species, and sometimes growth promotion to boost feed efficiency. Because extensive shrimp farming procedures increase the risk of pathogens, oxytetracycline, florfenicol, and quinolones are frequently used as medications added into feed or water. In places like Asia, where China and India control both manufacturing and consumption of antibiotics, this is particularly common.

### **Disease Pressures in Aquaculture**

Antibiotics are required to prevent mass mortality because of the perfect environment for bacterial growth created by high stocking densities, poor water quality, and stressed animals from fast growth demands. *Aeromonas hydrophila* and *Vibrio harveyi* are common infections in shrimp (e.g. whiteleg shrimp) and fish (such as European seabass and tilapia) that spread rapidly in semi-intensive systems without biosecurity. Since diagnostics don't keep up with rapidly expanding epidemics, prophylactic medication before symptoms appear is typical (Yuan et.al.,2023)

### **Misuse and Overuse Issues**

Non-science-based methods, such as utilizing sub-therapeutic dosages that fail to eradicate infections but choose survivors, or bulk dosing without veterinarian supervision, are the root cause of misuse. Continuous use in feed (up to 80% uneaten, leaving residues in sediments) and the persistence of prohibited medications like chloramphenicol because of poor disintegration are examples of overuse. 72% of farms in Bangladesh and Vietnam use antibiotics for stimulation and treatment, frequently going over acceptable limits.

### **Lack of Regulation**

In developing aquaculture hubs, poor implementation permits farmers to self-medicate and import uncontrolled, bypassing withdrawal periods and encouraging residues in products. Antibiotics like enrofloxacin are used by 73% of major manufacturers worldwide without consistent monitoring, which increases environmental release. Legislation varies between Mediterranean and Asian locales, with hotspots close to farms showing higher levels of resistant strains because residue limits are lacking.

## Emergence of Resistant Bacteria

During mutations and horizontal gene transfer, residues below minimum inhibitory concentrations continue to exert selective pressure, favoring resistant bacteria in water, sediments, and fish guts (e.g., plasmids expressing tetA, qnrS, sul1). Aquaculture ecosystems are dominated by multidrug-resistant *E. Coli*, *Vibrio*, and *Aeromonas*, which spread genes to human pathogens like *Salmonella* via seafood chains. This is accelerated by climate-driven warmth in areas such as the Mediterranean, which stresses bacterial physiology similarly to that of antibiotics (Pepi & Focardi, 2021).

## Consequences and Solutions

ARGs are increasingly common in sediments and exports worldwide, and resistant strains make treatments ineffective, increasing production costs and zoonotic hazards. Probiotics (e.g., *Bacillus* spp.), vaccinations, enhanced biosecurity, and stringent laws to reduce usage by giving priority to alternatives are all necessary One Health methods for mitigation. Research on gene monitoring and non-antibiotic treatments for sustainable farming has increased recently.

## One Health Concept Links Between Human Health, Animal Health, And Environmental Health

With the aim to address common threats like zoonoses, 75% of emerging diseases like COVID-19, Ebola, and avian influenza, which spread from animals due to habitat loss, wildlife trade, and intensive farming, and AMR, which is exacerbated by ecosystem degradation from pollution, deforestation, and climate change that breeds resistant pathogens in stressed wildlife and contaminated waters, the One Health approach emphasizes the interconnectedness of human, animal, and environmental health and advocates for multisectoral collaboration. Antibiotic-laden runoff from aquaculture and the introduction of multidrug-resistant bacteria like *Vibrio* and *Aeromonas* into rivers, sediments, and food chains are examples of environmental disruptions that make siloed interventions ineffective and call for integrated strategies. These strategies include biosecurity, probiotics over antibiotics, joint surveillance, and harmonized policies across WHO, FAO, and WOAHA (Adisasmito et.al., 2022).

## The AMR Cycle in Aquaculture

Up to 80% of antibiotics used in aquaculture remain uneaten or unmetabolized after being administered prophylactically or therapeutically in feed and water. These antibiotics, such as oxytetracycline and enrofloxacin, release sub-lethal residues into ponds, cages, and

surrounding waters that do not kill bacteria but instead put selective pressure on survivors. In fish and shrimp guts, water columns, and anoxic sediments that serve as long-term ARG reservoirs, these low concentrations cause resistance mechanisms such as efflux pumps (*tetA*), target mutations, enzymatic degradation (*sul1*), and horizontal gene transfer via plasmids and phages that enrich multidrug-resistant strains of *Vibrio*, *Aeromonas*, and *E. coli*. The cycle is closed when treated effluents re-enter farms and urban water supplies, perpetuating untreatable infections across One Health domains. Resistant bacteria (ARB) and genes (ARGs) spread downstream through effluent discharge into rivers and coastal zones, bioaccumulate in seafood via contaminated plankton and tissues, and spread to humans via consumption of shrimp or fish contaminated with residues or direct contact by farmers handling ponds (Ferri et.al., 2022).

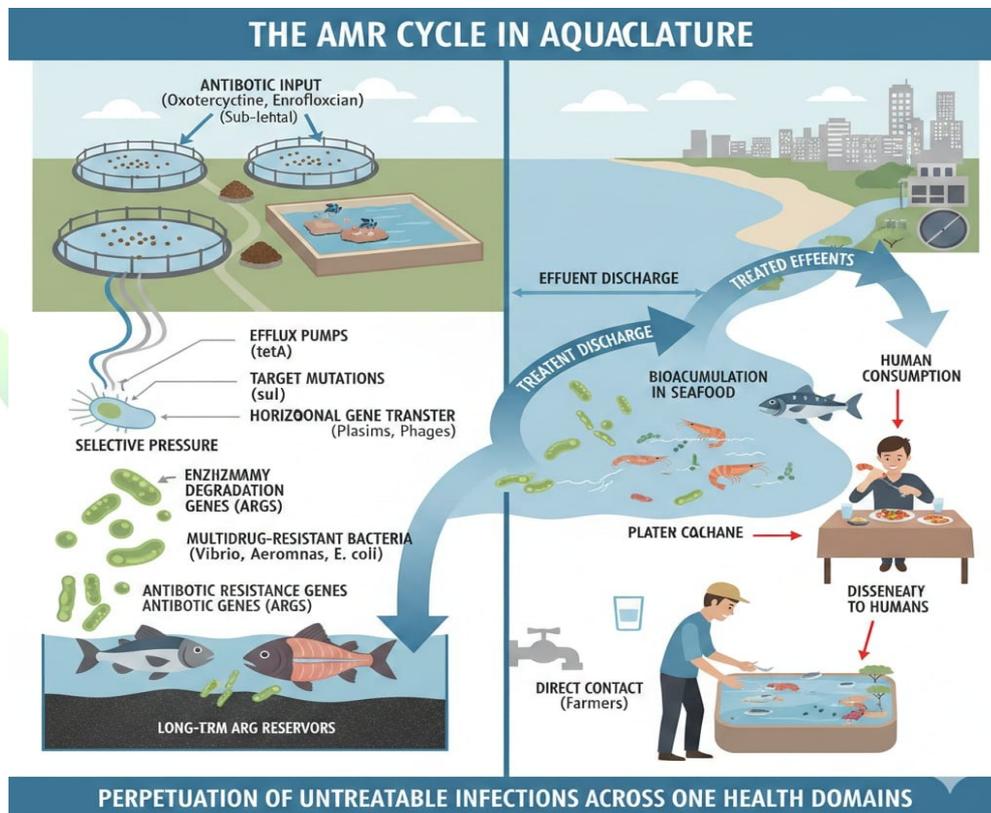


Fig. 1 AMR cycle in aquaculture

**Farm-Level Solutions: Healthy Fish, Less Antibiotics (Ferri et.al., 2022)**

Strategy	Key Components	Purpose / Outcome
Biosecurity Measures	Site isolation from wild fish; pond disinfection (lime/chlorine); water	Prevents pathogen entry and minimizes disease introduction at the farm level

	filtration; footbaths and gear sanitization; quarantine of SPF seeds (2–4 weeks)	
Good Farm Management	Low stocking density; water quality monitoring (DO >5 mg/L, pH 7–8.5, low ammonia); aeration; balanced feeding (3–5% body weight); routine health checks and early culling	Reduces stress and disease risk, maintaining healthy stocks without antibiotic use
Probiotics Application	Bacillus subtilis, Lactobacillus spp.; 10 <sup>6</sup> –10 <sup>9</sup> CFU/kg feed; preventive dosing via feed or water	Enhances gut health, outcompetes Vibrio, improves immunity; reduces infection rates by 40–60%
Vaccines Use	Injectable, bath, or oral vaccines targeting Aeromonas, Vibrio, Streptococcus; autogenous vaccines from farm isolates	Provides 70–95% protection; reduces mortality and antibiotic dependency
Immunostimulants Role	Beta-glucans, chitin, yeast extracts (0.1–0.5% in feed); stimulates phagocytosis and lysozyme activity	Boosts non-specific immunity for 2–4 weeks; lowers disease susceptibility by 30–50% without resistance risk

### Environmental Protection as AMR Control

Since 70–80% of uneaten medications end up as persistent residues in sediments that serve as long-term reservoirs for resistance genes like tetA and qnrS, proper waste and effluent management in aquaculture—such as settling ponds, biofilters, or recirculating aquaculture systems (RAS) prevents antibiotics and resistant bacteria from leaking into nearby rivers, mangroves, and coastal ecosystems. By preventing horizontal gene transfer among aquatic

bacteria through buffer zones, decreased water exchange, and sludge disposal, ecosystems are protected against amplification in biodiversity hotspots that may introduce resistant *Vibrio* strains back to farms or wildlife. Given that uncontrolled discharge has increased ARG abundance close to Asian shrimp farms by orders of magnitude, this multisectoral protection disrupts the cycle of AMR transmission, protecting environmental health and facilitating sustainable production in accordance with One Health principles.

### **Safeguarding Human Health**

Through skin contact, aerosol inhalation, or accidental ingestion during pond maintenance, aquaculture workers are directly exposed to antibiotic-resistant bacteria such as multidrug *Vibrio* and *Aeromonas*, which can cause chronic skin infections or gastrointestinal disorders that are resistant to conventional medications. Processing plant workers and consumers who consume undercooked seafood run the danger of consuming residues or viable resistant strains, which can lead to community-acquired AMR diseases like *Salmonella* or resistant *E. coli*. Research has also linked imported shrimp to increased quinolone resistance in people. By prioritizing food safety through mandatory withdrawal periods, residue testing (e.g., HPLC for oxytetracycline limits <0.1 mg/kg), cooking to 63°C, and hygiene practices like handwashing and gloves, zoonotic transmission chains are broken and public health is protected from aquaculture-sourced AMR under One Health.

## **Role of Policy, Science, and Surveillance**

### **Responsible Antibiotic Policies**

For the purpose to prevent misuse and guarantee trade compliance across One Health sectors, effective policies enforce withdrawal periods, prohibit growth promoters like chloramphenicol, require veterinary prescription-only access to antibiotics, and set maximum residue limits (MRLs) in aquaculture products. They also harmonize national regulations with international standards from the FAO/WHO.

### **AMR Monitoring Programs**

For the purpose to minimize zoonotic spill over, national surveillance networks use WGS and PCR to monitor antibiotic usage, resistance genes (ARGs like *tetA*), and bacterial isolates from farms, effluents, fisheries, and hospitals. This allows for the early identification of hotspots and the assessment of the effects of interventions.

## Research and Diagnostics

While financing alternatives like nanobodies, ongoing research creates phage therapeutics, quorum quenchers, and quick diagnostics (e.g., LAMP assays for *Vibrio*); farm-level kits for on-site AMR screening speed up precise interventions over blind dosing.

## Farmer Education

Farmers are empowered to adopt low-antibiotic models through training programs that teach biosecurity, probiotics, and record-keeping through extension services; certified schemes encourage compliance, promoting behavioral change for sustainable, resistance-free production (Frota et.al., 2026).

## Why One Health Is the Way Forward

Considering the One Health approach integrates human, animal, and environmental health to address interrelated issues like disease outbreaks, antimicrobial resistance (AMR), and ecosystem degradation, coordinated effort across sectors is crucial for sustainable aquaculture. One Health encourages proactive measures like strong biosecurity protocols, vaccination programs, and water quality monitoring in fish farms by fostering collaboration among veterinarians, aquaculture producers, environmental scientists, policymakers, and public health experts. These measures minimize disease incidence and reduce reliance on antibiotics, which is crucial for maintaining their efficacy for future treatments of humans and animals. In the end, resilient food systems that provide nutrient-dense seafood without endangering the health of the planet or speeding up AMR globally are supported by sustainable practices like probiotic-enriched feeds, integrated multi-trophic aquaculture (such as aquaponics), and surveillance for zoonotic pathogens. These practices also improve fish welfare, guarantee food safety, and lessen environmental impacts from waste and invasive species. Through limiting the spread of resistance genes through shared aquatic ecosystems, this multidisciplinary approach not only promotes economic viability for communities that depend on aquaculture but also protects antibiotic effectiveness for future generations.

## A Call to Action

### Call to Farmers

To stop the development of AMR in fish farms, aquaculture growers must put One Health first by enforcing stringent biosecurity protocols, choosing probiotics over antibiotics, and keeping an eye on the quality of the water. By reducing disease pressure and maintaining antibiotic efficacy, combined pest management and vaccination improve farm sustainability and profitability.

### **Call to Policymakers**

Authorities should support cross-sector partnerships, encourage sustainable feeding, and enforce One Health policies like AMR surveillance in aquaculture. Long-term food security and public health will be protected by outlawing unnecessary antibiotics and encouraging environmentally favourable behaviours.

### **Call to Researchers**

By investigating quorum quenching, pathogen genomes, and alternate treatments like phage therapy, researchers can further One Health. Developing AMR-resistant strains and early-warning systems through interdisciplinary collaboration will yield evidence-based resources for aquaculture that is sustainable.

### **Call to Consumers**

By supporting local sustainable farms, selecting certified antibiotic-free seafood, and pushing for clear labelling, consumers can effect change. Making educated decisions puts pressure on the supply chain to comply with One Health, which lowers market demand for AMR-prone items (Danasekaran, R. (2024).

### **Conclusion**

As this article discusses, antimicrobial resistance (AMR) in aquaculture is a developing worldwide concern that goes well beyond fish and shrimp farms, tying environmental contamination, animal disease control, and human health into a single interwoven crisis. Multidrug-resistant bacteria like *Vibrio* and *Aeromonas* have become more prevalent due to the overuse and frequently uncontrolled use of antibiotics in aquaculture. These bacteria survive in pond water, sediments, and seafood products before making their way into the environment and food chains to reach consumers and healthcare systems. By decreasing the efficiency of life-saving antibiotics, these resistant organisms jeopardize public health, raise production costs, jeopardize export markets, and undermine the efficacy of treatments. Moving past reactive antibiotic use and toward a preventive, science-based paradigm based on the One Health approach—which acknowledges the interconnectedness of environmental, animal, and human health—is necessary to address this dilemma. Aquaculture systems can drastically lower antibiotic pressure while preserving productivity and profitability by enforcing stringent biosecurity, enhancing surveillance of resistance genes, adopting probiotics and vaccines, improving water quality management, bolstering regulatory oversight, encouraging responsible antibiotic stewardship, and educating farmers and stakeholders. Sustainable seafood production depends not on developing stronger drugs, but on coordinated action, ecological

responsibility, and cross-sector collaboration that protects aquatic ecosystems, safeguards consumer health, and preserves antimicrobial effectiveness for future generations.

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