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Fish health, environmental contaminants, and disease management in Ghanaian aquaculture: A systematic review

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Abstract

Fish health significantly influences aquaculture productivity, sustainability, food security, and public health. Despite Ghana's rapid aquaculture expansion, the sector remains constrained by widespread disease outbreaks and environmental threats. This systematic review synthesizes existing literature (2010–2024) to comprehensively assess fish health issues, management practices, diagnostic capabilities, environmental threats, and policy implications in Ghana. Following PRISMA guidelines, 65 eligible studies were selected from an initial 386 records and critically appraised using the Mixed Methods Appraisal Tool (MMAT). Findings indicate that bacterial pathogens (notably *Streptococcus* and *Aeromonas* spp.), viral infections such as Infectious Spleen and Kidney Necrosis Virus (ISKNV), parasitic infestations, and emerging fungal pathogens constitute major disease threats. Environmental stressors such as heavy metals, pesticides, and microplastics were frequently detected in aquaculture-associated water bodies, raising ecological and food safety concerns. Although molecular diagnostic tools

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are increasingly being adopted, national diagnostic coverage remains uneven. Widespread antibiotic misuse, weak biosecurity implementation, and regulatory gaps further exacerbate fish health risks. This review provides the first integrated synthesis linking disease epidemiology, environmental contamination, diagnostic capacity, farmer practices, and governance challenges within Ghana's aquaculture sector. Strengthening surveillance systems, improving diagnostic infrastructure, enhancing farmer training, and enforcing regulatory frameworks are essential to improving resilience and sustainability. The findings offer policy-relevant insights applicable to emerging aquaculture systems across sub-Saharan Africa and other developing regions.

KEYWORDS

antibiotic resistance, aquaculture, biosecurity, diagnostic tools, disease prevalence, environmental contaminants, fish health, Ghana

1 | INTRODUCTION

Fish health management is an essential element of sustainable aquaculture, significantly impacting food security, nutritional quality, and economic stability in developing countries like Ghana (FAO 2021). With a growing population and an increasing demand for animal protein, aquaculture has emerged as a critical solution to addressing nutritional deficits and promoting economic growth (Hasselberg et al., 2020; Tall & Failler, 2012). However, maintaining healthy fish populations is increasingly challenging due to various environmental stressors, pathogens, and inadequate management practices. Fish diseases and related health issues directly influence productivity, profitability, and the overall sustainability of the aquaculture sector.

Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) are the major cultured fish species in Ghana for their tolerance to stress, acceptance on the domestic market, and high growth rate (Sey et al., 2021). Tilapia alone comprises over 80% of domestic production. Despite these achievements, occurrences of diseases (especially bacterial infections, novel viral pathogens such as Infectious Spleen and Kidney Necrosis Virus (ISKNV), parasitic infestations, and fungal pathogens) have generally compromised productivity from time to time (Diyie et al., 2022 & 2024). The increasing prevalence of antimicrobial resistance (AMR) adds an additional challenge to the control of diseases and causes concern that is not only related to aquaculture but also to other public health aspects (Agbeko et al., 2022; Dandi et al., 2025).

Such biological challenges take place in the wider context of pollution of aquatic systems. Heavy metals, pesticide residues, polycyclic aromatic hydrocarbons, and microplastics (MP) have been found in main waterbodies associated with aquaculture activities such as Lake Volta, Densu River basin, and the coastal systems (Blankson et al., 2025; Bruce-Vanderpuije et al., 2025; Asamoah et al., 2021; Kwaansa-Ansah et al., 2019; Gbogbo et al., 2017). Although the exposure routes of pollutants may be different in cage culture and pond-based finfish culture, the contamination present in source waters, and sometimes from feed ingredients, can pose risks to fish health and public health. The growing incidence of microplastics (MP) detection in fish tissue is yet another evidence of the expanding interface between environmental degradation and aquaculture production systems.

In addition to these biological and environmental stressors, challenges of systemic management and governance have compounded (Nkansah 2017; Steinhausen et al., 2022; Orou-seko et al., 2024). Poor biosecurity and antibiotic stewardship, insufficient diagnostic capabilities, infrastructure or standards, and lax legislative enforcement of regulations diminish the industry's ability to control new health challenges. Low levels of knowledge among farmers and a lack of extension services also limit the use of preventive health measures.

Although numerous studies have examined specific dimensions of fish health in Ghana such as pathogen identification, AMR, heavy metal contamination, farmer knowledge, attitude, and practices (Magna et al., 2021&2024; Ndraha et al., 2024; Ndashe et al., 2023; Mark et al., 2019), these investigations remain fragmented across disciplines and geographical settings. Existing evidence is dispersed among microbiological studies, environmental toxicology assessments, epidemiological surveys, and governance analyses, limiting the ability of policymakers and practitioners to derive integrated, actionable insights. Also, emerging challenges such as ISKNV outbreaks, increasing AMR, and microplastic contamination have evolved rapidly in recent years. However, no comprehensive systematic synthesis has consolidated these developments in a unified framework. As a result, decision-makers face difficulties in linking disease dynamics with environmental drivers, diagnostic capacity gaps, and regulatory weaknesses.

Unlike prior fragmented review studies, this systematic review distinctly integrates fish disease epidemiology, environmental contaminants, diagnostic capacity, farmer KAP, and regulatory governance in a single synthesis, applies a PRISMA-guided systematic framework, conducts methodological quality appraisal using MMAT, synthesizes emerging issues on ISKNV genomic surveillance, AMR governance, and microplastics from 2010 to 2024, and provides integrated policy-relevant recommendations.

Essentially, the main objective of this systematic review was to critically assess the current state of knowledge on fish health management practices, diagnostic capabilities, environmental threats, and associated human health risks within Ghanaian aquaculture systems while identifying gaps and deriving recommendations for sustainable production.

2 | MATERIALS AND METHODS

2.1 | Study design

This study employed a systematic review methodology guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Figure 1) to ensure transparency, reproducibility, and methodological rigor (Higgins et al., 2022; Page, McKenzie, et al., 2021; Page, Moher, et al., 2021; Syanya et al., 2025). The review aimed to synthesize empirical evidence relating to fish health, environmental contaminants, diagnostic practices, management approaches, and regulatory challenges in Ghanaian aquaculture between January 2010 and December 2024.

2.2 | Search strategy

A comprehensive literature search was conducted using Google Scholar and supplementary database searches to capture peer-reviewed journal articles and scholarly theses. Search strings combined Boolean operators and relevant keywords, including “fish health Ghana,” “aquaculture disease Ghana,” “ISKNV Ghana,” “antibiotic resistance aquaculture Ghana,” “microplastics Ghana fish,” and “heavy metals aquaculture Ghana.” Reference lists of identified articles were also screened to capture additional relevant studies.

2.3 | Eligibility criteria and study selection

Studies were included if they: (i) were published between 2010 and 2024; (ii) were conducted within Ghanaian aquatic systems; (iii) addressed fish diseases, pathogens, environmental contaminants, biosecurity practices,

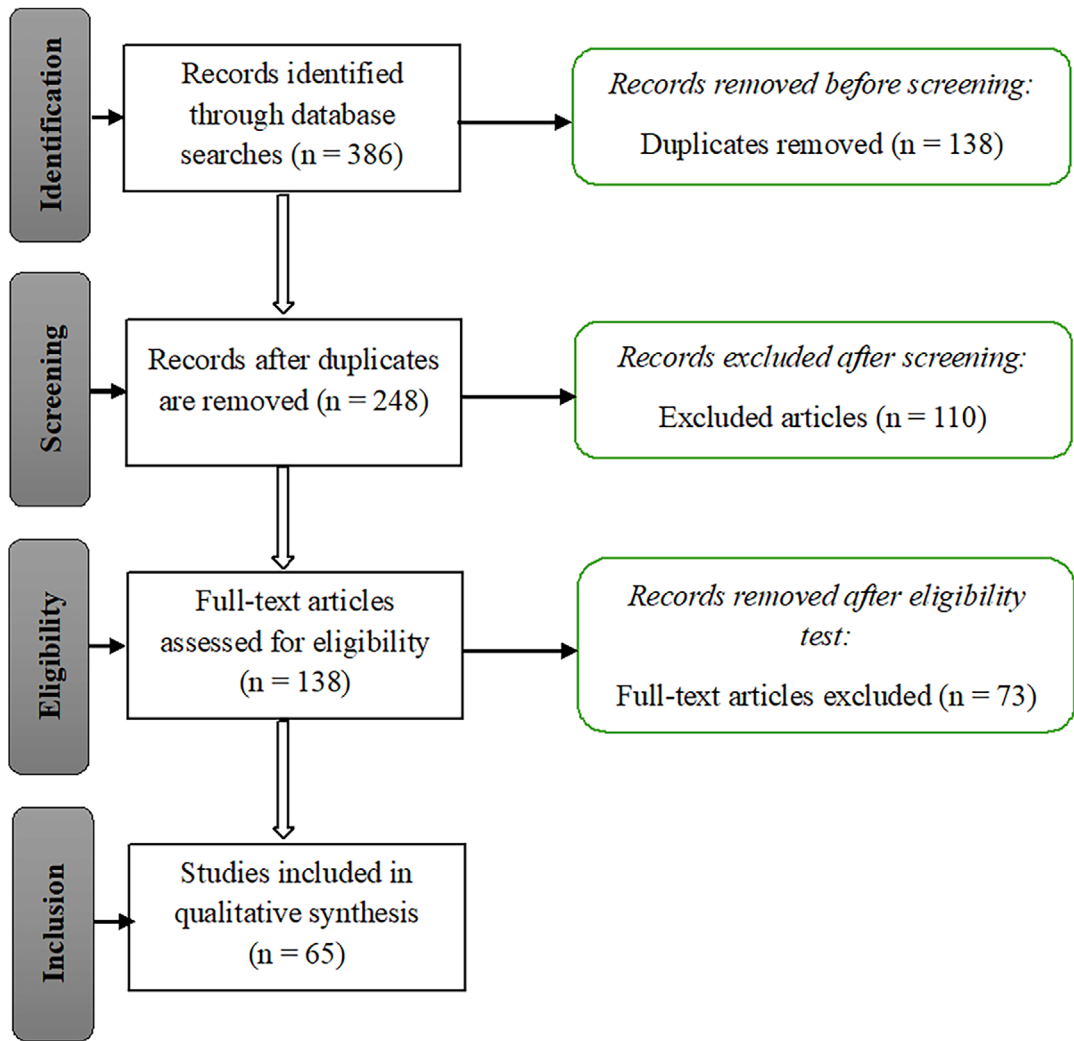


FIGURE 1 PRISMA flow diagram showing the study selection process. (Adapted from Syanya et al. (2025)).

diagnostic tools, or related human health implications; and (iv) presented empirical data using qualitative, quantitative, or mixed-method approaches. Studies were excluded if they were non-peer-reviewed commentaries, conference abstracts, editorials, non-English publications, or research conducted entirely outside Ghana. All retrieved records were screened first by title and abstract to remove duplicates and irrelevant studies. Full-text screening was subsequently conducted against predefined inclusion criteria.

2.4 | Data extraction and synthesis

A structured data extraction template was developed to ensure uniformity. Extracted information included study characteristics (design, location, species), pathogen type, diagnostic methods, contaminant profiles, management practices, farmer knowledge metrics, and key findings. Data extraction was independently verified by two reviewers to enhance accuracy and minimize bias (Table 1).

TABLE 1 Structured data extraction framework for included studies.

Category	Data items extracted
General article information	• Authors • Year of publication • Journal/Publisher
Study characteristics	• Study design (e.g., cross-sectional, experimental, longitudinal) • Geographic location within Ghana • Type of aquatic environment (ponds, cages, reservoirs, lakes, hatcheries) • Species studied
Sample characteristics	• Sample size • Species specificity • Nature of samples (tissue, water, sediment, whole fish, feed, etc.)
Disease/pathogen information	• Pathogen type(s) identified (bacteria, viruses, parasites, fungi) • Diagnostic tools/methods used (culture, PCR, histology, microscopy) • Prevalence and epidemiological data
Environmental contaminants	• Types of contaminants reported (heavy metals, microplastics, pesticides, etc.) • Concentration levels • Measurement/analytical techniques used
Health management & biosecurity measures	• Disease prevention and control strategies • Biosecurity protocols applied • Health monitoring practices
Farmer knowledge, attitudes, and practices (KAP)	• Knowledge of disease causes and risks • Attitudes toward biosecurity/compliance • Farm-level practices documented
Major findings	• Key outcomes and trends reported in the study
Conclusions and recommendations	• Key conclusions drawn • Suggested interventions, policy implications, and research needs

Given the heterogeneity of study designs and outcome measures, a narrative synthesis approach was adopted rather than meta-analysis (Aromataris & Munn, 2020; Popay et al., 2006). Findings were organized into thematic categories: (i) disease prevalence and pathogen types; (ii) diagnostic methodologies; (iii) environmental contaminants; (iv) fish health management practices; (v) farmer knowledge and behavior; and (vi) regulatory and governance frameworks. Patterns, methodological limitations, and policy implications were subsequently interpreted across themes.

2.5 | Quality appraisal

Methodological quality of included studies was assessed using the Mixed Methods Appraisal Tool (MMAT), which allows standardized evaluation across qualitative, quantitative, and mixed-method designs (Hong et al., 2018). Criteria assessed included clarity of research questions, adequacy of sampling, validity of measurement tools, transparency of analysis, and management of potential bias (Table 2).

TABLE 2 Mixed Methods Appraisal Tool (MMAT) quality appraisal of included studies ($n = 65$). Mean MMAT score = $83.5 \pm 8.2\%$.

Study ID	Author(s) (year)	Study type	Species studied	Focus area	MMAT score (%)	Methodological rigor
S1	Diye et al. (2022)	Quantitative (Cross-sectional)	<i>O. niloticus</i>	Bacterial pathogens & antibiotic resistance	90	High
S2	Alathari et al. (2023)	Experimental (Molecular)	<i>O. niloticus</i>	Viral pathogen (ISKNV) detection	95	High
S3	Ayiku et al. (2024)	Quantitative (Genomic)	<i>O. niloticus</i>	Viral surveillance (ISKNV)	85	High
S4	Agbeko et al. (2022)	Mixed-method	<i>O. niloticus</i> , <i>C. gariepinus</i>	Antibiotic residues & resistance profiling	80	Moderate–High
S5	Kombat et al. (2024)	Quantitative	<i>O. niloticus</i>	Parasitic infestations (monogeneans)	75	Moderate
S6	Effah et al. (2021)	Environmental survey	Tilapia & Catfish	Heavy metal contamination	80	Moderate–High
S7	Bruce-Vanderpuije et al. (2025)	Lab–Field study	Marine & freshwater fish	Microplastics and contaminants	85	High
S8	Abarike, Atuna, et al. (2023)	Qualitative	<i>O. niloticus</i>	Farmer biosecurity practices	70	Moderate
S9	Dandi et al. (2024)	Mixed-method	Tilapia & Catfish	Antibiotic use, health practices	75	Moderate
S10	Sackey et al. (2024)	Environmental	Various species	Heavy metals, pesticides	90	High

2.6 | Overview of included studies

The included studies covered various geographic regions within Ghana, including the Volta Lake region, the Ankobra River, the Tono Reservoir, the Densu River Basin, coastal areas, and urban markets. The dominant species studied included Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*), reflecting their prominence within Ghana's aquaculture. Studies included diverse designs: observational studies (cross-sectional surveys), experimental laboratory investigations, environmental contaminant assessments, and epidemiological surveillance of pathogens.

2.7 | Methodological limitations of existing studies

Despite methodological diversity, several limitations emerged consistently across studies, including (i) limited longitudinal data, restricting understanding of temporal trends in fish health issues, (ii) insufficient sample sizes in some studies limiting generalizability, limited geographic and species diversity, with a predominant focus on widely farmed species, neglecting lesser-known or indigenous species, (iii) variability in diagnostic accuracy, with some studies relying on less precise methodologies or a lack of advanced molecular tools.

2.8 | Analysis of gaps identified

Critical gaps identified from the methodological and thematic synthesis included insufficient surveillance and routine monitoring systems for disease outbreaks and environmental contaminants, limited diagnostic capacity at local levels,

restricting timely detection and management of outbreaks, significant knowledge-practice gaps among fish farmers regarding biosecurity measures and prudent use of antibiotics, and weaknesses in regulatory frameworks and policy implementation regarding antibiotic use, pesticide control, and environmental management. These gaps represent vital areas for future research and practical intervention.

3 | RESULTS

3.1 | Overview of included studies

This systematic review analyzed 65 articles selected after rigorous screening, all meeting the established eligibility criteria and explicitly focused on fish health within Ghanaian aquaculture systems between 2010 and 2024. The studies varied methodologically, including observational cross-sectional studies, experimental research, environmental monitoring, laboratory diagnostics, and qualitative assessments involving farmer knowledge, attitudes, and practices. Geographically, studies spanned regions including Volta Lake, the Ankobra River, the Densu River Basin, coastal marine ecosystems, and various freshwater reservoirs across Ghana. Dominant fish species studied were Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*), reflecting their widespread cultivation and economic significance. Major thematic areas addressed in these studies include disease prevalence, pathogens, environmental contaminants, health management and biosecurity practices, and human health implications of aquaculture practices.

3.2 | Thematic synthesis of findings

3.2.1 | Disease prevalence and types

Fish diseases significantly threaten Ghana's aquaculture sector, primarily driven by bacterial, viral, and parasitic pathogens. Numerous studies have reported bacterial infections as prevalent, particularly involving *Streptococcus* spp., *Aeromonas* spp., and antibiotic-resistant strains, with major impacts on ulceration, hemorrhage, and mortality (Table 3). For instance, Diyié et al. (2022) reported high prevalence of bacterial pathogens in cultured Nile tilapia from various fish farms, using multiplex PCR assays for rapid pathogen detection. Similarly, Agbeko et al. (2022) identified antibiotic-resistant bacteria across fish farms in Ghana, with pathogens demonstrating resistance to commonly used antibiotics like tetracycline and amoxicillin. Viral diseases, particularly Infectious Spleen and Kidney Necrosis Virus (ISKNV), emerged as critical threats, significantly impacting tilapia farming on Lake Volta. Studies by Alathari et al. (2023) and Ayiku et al. (2024) used genomic surveillance methods, revealing widespread ISKNV infections that cause significant systemic disease and mortality in farmed tilapia. Parasitic infections also posed considerable threats, as documented by Kombat et al. (2024), who reported high infestation rates of ectoparasites, such as monogeneans, in cultured Nile tilapia in Northern Ghana, and Diyié et al. (2024) in Southern Ghana, using conventional and molecular diagnostic tools. Such parasites compromise fish health by damaging gills, impairing growth, weakening immune responses, and increasing vulnerability to secondary infections. Ramirez-Paredes et al. (2021) reported mixed/co-infections of ISKNV with *Streptococcus agalactiae* and other tilapia bacterial pathogens in farms in both fish and fish feed (Diyié et al., 2024) on the Volta Lake, while Deho et al. (2019) and Diyié et al. (2024) observed fungal infections in farmed tilapia and catfish in Ghanaian aquaculture, with similarity and homology of the sequences of isolated species showing close relationships with five fungal genera, *Leucosporidium*, *Rhodotorula*, *Aspergillus*, *Eurotium*, and *Neosartorya* at greater than 85% identity. These categories of pathogens, reportedly, affect farmed fish in varying proportions, with bacterial infections exhibiting the highest prevalence and fungal pathogens the lowest (Figure 2).

TABLE 3 Major pathogen categories identified in Ghanaian aquaculture (2010–2024).

Pathogen type	Common genera/species	Typical hosts	Major impact	References
Bacterial	<i>Streptococcus</i> , <i>Aeromonas</i> , <i>Pseudomonas</i>	<i>O. niloticus</i> , <i>C. gariepinus</i>	Ulceration, hemorrhage, mortality	(Abarike et al., 2022; Agbeko et al., 2022; Dayie et al., 2024; Diyiye et al., 2022)
Viral	ISKNV, TiLV (suspected), Iridoviridae	<i>O. niloticus</i>	High mortality, systemic infection	(Alathari et al., 2024; Ayiku et al., 2024; Ramírez-Paredes et al., 2021)
Parasitic	Monogeneans, Ichthyophthirius, Trichodina	Tilapia & Catfish	Gill damage, growth retardation	(Dandi et al., 2024; Kombat et al., 2024)
Fungal	<i>Saprolegnia</i> spp., <i>Aspergillus</i> sp., <i>Candida</i> sp.	Tilapia & Catfish	Secondary infection, egg mortality	Dandi et al. (2024)
Mixed/ Co- infection	Multiple	Tilapia	Reduced survival, complex pathology	(Abarike, Dandi, & Ampofo- Yeboah, 2023; Ramírez-Paredes et al., 2021)

3.2.2 | Diagnostic tools and pathogen identification

The reviewed literature highlights significant variability in diagnostic capacities across Ghana (Figure 3). While traditional diagnostic methods such as microbial culturing remain prevalent, studies increasingly advocate the use of advanced molecular techniques to improve pathogen detection accuracy. Diyiye et al. (2022); Dayie et al. (2024) demonstrated the reliability and speed of multiplex PCR assays, qPCR, and sequencing for identifying bacterial, fungal, and parasitic pathogens in aquaculture systems. Similarly, Alathari et al. (2023) emphasized the efficiency of genomic surveillance using environmental DNA (eDNA) for detecting ISKNV in Lake Volta, significantly improving diagnostic sensitivity and specificity compared to traditional methods. Despite these advances, several studies noted ongoing reliance on conventional microbiological techniques (Agbeko, 2020; Dayie et al., 2024), indicating a gap between available technology and practical implementation, likely due to limited resources, technical expertise, and infrastructure.

3.2.3 | Health management practices

Fish health management practices were consistently described as inadequate across reviewed studies, significantly contributing to disease prevalence and outbreaks. Common management deficiencies reported included poor sanitation, inadequate water quality management, inappropriate feed handling, and limited biosecurity protocols (Abarike, Dandi, & Ampofo-Yeboah, 2023; Dandi et al., 2024). Farmers frequently adopted reactive rather than preventive health strategies, relying heavily on antibiotic usage without veterinary guidance, as noted by Agoba et al. (2017). Excessive and inappropriate antibiotic use emerged as a widespread concern, exacerbating antibiotic resistance and environmental contamination (Dandi et al., 2025). Proactive measures like routine health monitoring, vaccination, and probiotics application remained infrequently implemented, primarily due to limited awareness, training, and resource availability. Figure 4 presents adoption rates of fish health management practices across farms, revealing overreliance on antibiotics (60%) and low uptake of biosecurity (35%) and vaccination measures (10%).

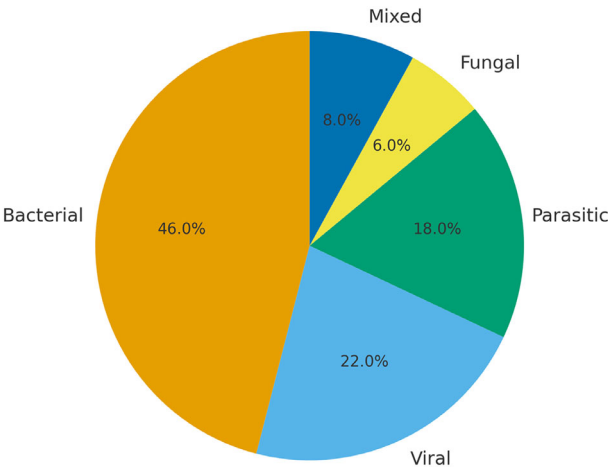


FIGURE 2 Proportion of pathogen types in Ghanaian aquaculture (2010–2024). (Synthesized from included studies ($n = 65$), including Agbeko et al. (2022); Alathari et al. (2024); Ayiku et al. (2024); Dandi et al. (2024); Diyie et al. (2022); Kombat et al. (2024); Ramírez-Paredes et al. (2021)).

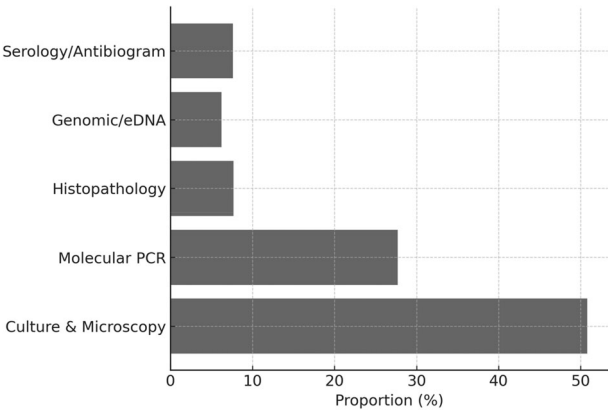


FIGURE 3 Diagnostic methods applied in the reviewed studies. (Derived from methodological data extracted from included studies (2010–2024), including Alathari et al. (2024); Agbeko et al. (2022); Ayiku et al. (2024); Dandi et al. (2024); Diyie et al. (2022)).

3.2.4 | Environmental and feed-related factors

Environmental contaminants significantly impact fish health in Ghanaian aquaculture. Heavy metals, microplastics, pesticides, and pharmaceutical residues have been consistently documented in major water bodies used for aquaculture, posing significant health risks to both fish and consumers (Figure 5). Heavy metal contamination is particularly prevalent, with studies by Effah et al. (2021), Sackey et al. (2024), and Blankson et al. (2025) identifying hazardous concentrations of mercury, lead, arsenic, and cadmium in fish from the Ankobra River and some freshwater reservoirs, which are sources of water for inland aquaculture. These contaminants cause chronic health impacts in fish, including impaired reproduction, growth inhibition, and compromised immunity, subsequently affecting human consumers through biomagnification along food chains (Kwaansa-Ansah et al., 2019). However, in intensive culture systems with relatively short production cycles, the magnitude of biomagnification may be limited compared to wild species. Microplastic contamination has recently attracted substantial attention due to widespread occurrences in

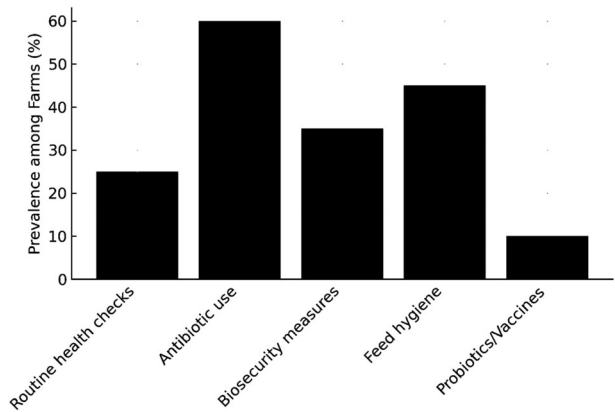


FIGURE 4 Health management practices in Ghanaian aquaculture. (Reproduced from farmer survey and management studies, including Abarike, Atuna, et al. (2023); Agoba et al. (2017); Dandi et al. (2024); Dandi et al. (2024, 2025)).

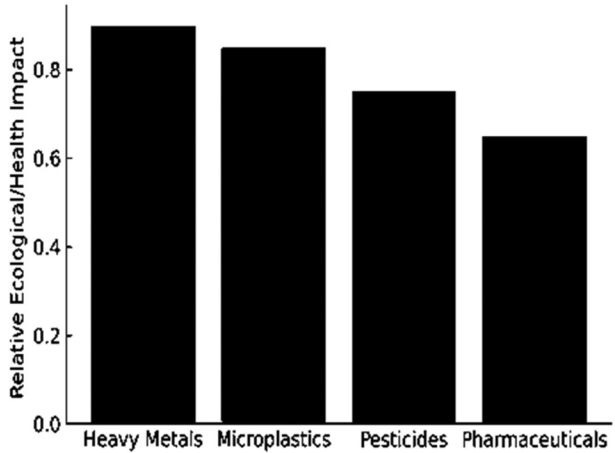


FIGURE 5 Environmental contaminant impact on aquaculture health on a scale of 0–1. (Generated from contaminant assessment studies, including Bandowe et al. (2014); Blankson et al. (2025); Bruce-Vanderpuije et al. (2025); Effah et al. (2021); Kwaansa-Ansah et al. (2019); Pappoe et al. (2022)).

fish tissues, particularly the gastrointestinal tracts and gills. Nuamah et al. (2023), Boateng et al. (2024), and Bruce-Vanderpuije et al. (2025) found significant microplastic accumulation in fish species from coastal and freshwater ecosystems, suggesting extensive environmental plastic pollution and its detrimental ecological impacts. Pesticide residues, notably organochlorine compounds, are also widely reported contaminants that pose severe chronic toxicity risks to fish populations. Fianko et al. (2011) and Kuranchie-Mensah et al. (2013) reported persistent pesticide residues in fish tissues from the Densu River Basin, which is an emerging hub for aquaculture, raising significant concerns about long-term ecosystem health and food safety.

3.2.5 | Biosecurity and regulatory issues

The reviewed studies consistently noted inadequate biosecurity measures and weak regulatory oversight across Ghanaian aquaculture operations. The radar chart (Figure 6) depicts major compliance gaps across quarantine,

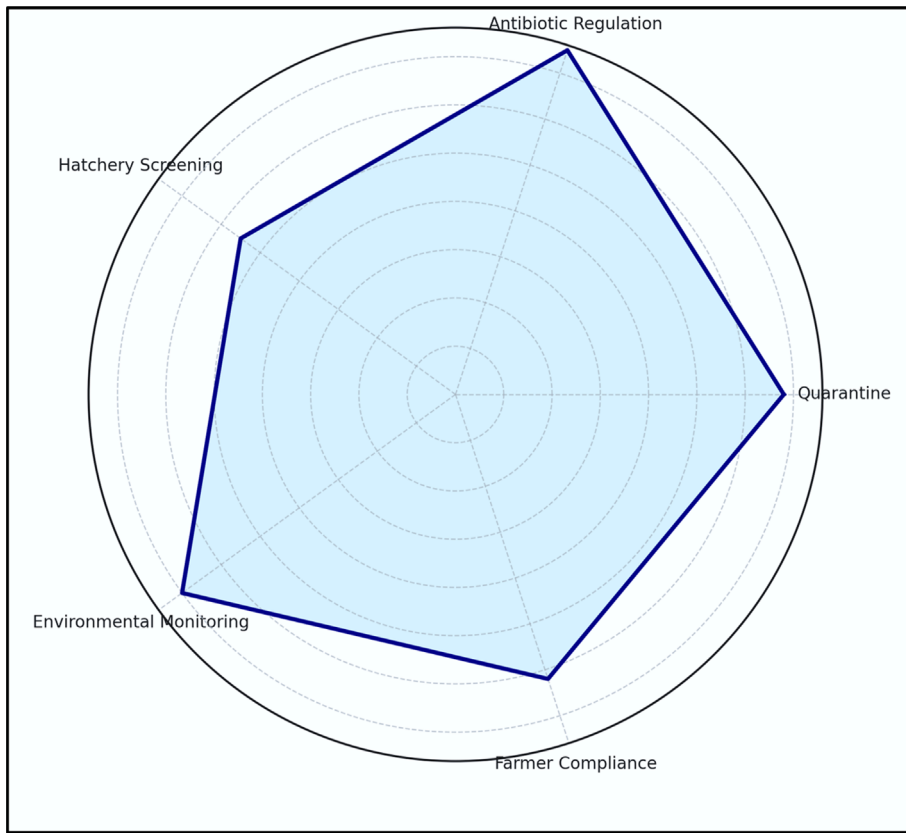


FIGURE 6 Biosecurity and regulatory compliance gaps in Ghanaian aquaculture. (Derived from governance and biosecurity studies including Agoba et al. (2017); Dandi et al. (2024, 2025); Magna, Tornyie, et al. (2024); Zornu et al. (2023)).

antibiotic regulation, hatchery screening, and environmental monitoring within Ghanaian aquaculture operations. Issues such as irregular implementation of quarantine protocols, poor hygiene practices, unregulated movement of live fish stocks, and unmonitored antibiotic applications were widespread, significantly increasing the risk of disease transmission (Agoba et al., 2017; Dandi et al., 2024). Regulatory gaps further exacerbate these issues, as studies frequently cited insufficient enforcement of environmental safety standards, weak oversight of antibiotic usage, and limited governmental capacity for routine monitoring (Magna, Tornyie, et al., 2024; Zornu et al., 2023). Such gaps pose significant challenges for policy implementation, requiring strengthened institutional frameworks, comprehensive policy reforms, and robust monitoring systems.

3.2.6 | Farmer knowledge, attitudes, and practices (KAP)

Several studies emphasized limited farmer awareness and knowledge gaps concerning fish health management practices. Farmers often demonstrated inadequate understanding of biosecurity, antibiotic use, disease identification, and environmental management practices (Abarike, Dandi, & Ampofo-Yeboah, 2023; Dandi et al., 2024). Qualitative assessments highlighted farmers' reliance on experiential knowledge rather than on scientifically grounded practices, leading to suboptimal health management and biosecurity measures. Figure 7 shows farmer KAP levels, highlighting low practical adoption and limited training exposure, despite positive attitudes toward adopting best management

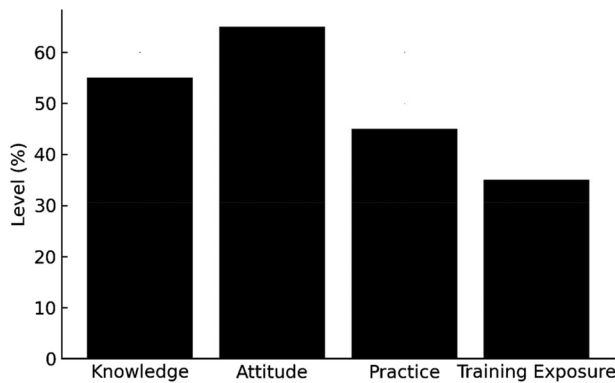


FIGURE 7 Farmer knowledge, attitude, and practice (KAP) levels in fish health management. Synthesized from KAP studies among fish farmers in Ghana, including Abarike, Atuna, et al. (2023); Dandi et al. (2024, 2025).

practices. Such gaps underscore the need for targeted training programs, extension services, and community-based education initiatives to bridge knowledge-practice gaps effectively.

3.3 | Policy and practical implications

This review highlights several critical areas for policy intervention and practical implementation:

1. **Enhanced Regulatory Frameworks:** Robust policy enforcement mechanisms addressing antibiotic use, environmental contaminant controls, and biosecurity compliance are imperative. Effective implementation requires strengthening governmental oversight capabilities and establishing clear regulatory guidelines.
2. **Investment in Diagnostic Infrastructure:** Expanding laboratory capabilities, incorporating advanced molecular diagnostics, and training specialized personnel will significantly enhance disease surveillance, early detection, and timely interventions, thus reducing disease-related economic losses.
3. **Farmer Education and Capacity Building:** Extensive training programs focused on biosecurity practices, disease prevention measures, prudent antibiotic use, and sustainable aquaculture management are essential. Extension services should prioritize community-based, participatory educational approaches to achieve greater effectiveness and adoption.

Systematic Surveillance Programs: Establishing comprehensive disease surveillance systems with standardized reporting mechanisms and routine health assessments is critical for early disease detection and effective response management, significantly enhancing aquaculture resilience.

3.4 | Analysis of gaps identified

A comprehensive synthesis identified critical gaps in diagnostic capabilities, surveillance mechanisms, management practices, and regulatory frameworks, significantly affecting the sustainability and productivity of Ghanaian aquaculture systems. Primary identified gaps include

1. **Limited diagnostic capacity and infrastructure:** Insufficient access to advanced diagnostic tools and trained personnel hampers timely disease detection and response,

2. Weak disease surveillance and monitoring systems: Inadequate systematic surveillance leads to delayed outbreak identification, increasing economic losses and disease spread,
3. Inadequate management and biosecurity protocols: Widespread deficiencies in sanitation, feed management, and biosecurity measures exacerbate pathogen transmission and contamination risks,
4. Knowledge and awareness deficits among farmers: Persistent gaps in farmer knowledge regarding effective health management practices reduce proactive disease prevention efforts,
5. Regulatory and policy implementation challenges: Weak regulatory enforcement, particularly concerning antibiotic use and environmental contaminants, undermines sustainability efforts and public health safety.

3.5 | Under-researched areas

Certain critical areas remain significantly under-researched, limiting comprehensive understanding and effective management of fish health in Ghana. Notable gaps include:

- Comprehensive longitudinal epidemiological studies tracking disease prevalence trends.
- Impact assessments of emerging environmental contaminants (e.g., pharmaceuticals, novel pesticides).
- Socio-economic analyses linking farmer education programs to improved health outcomes.
- Evaluations of alternative disease management practices (e.g., probiotics, herbal remedies, vaccines) and their scalability within local contexts.

3.6 | Methodological limitations in existing studies

Significant methodological limitations across studies were noted, particularly:

- Predominance of cross-sectional study designs limits temporal trend analyses.
- Small sample sizes, particularly in environmental contaminant studies, limit generalizability.
- Inconsistent application of standardized diagnostic and analytical methodologies.
- Limited geographic diversity, concentrating primarily on widely studied regions like Volta Lake, neglecting remote and less-studied ecosystems.

3.7 | Implications of gaps for research, policy, and practice

Identified gaps significantly affect fish health outcomes, underscoring an urgent need for integrated strategies to enhance diagnostic capacity, strengthen surveillance systems, improve farmer education, and bolster regulatory frameworks. Addressing these gaps through targeted research initiatives, capacity-building interventions, policy reforms, and cross-sectoral collaboration can significantly enhance aquaculture sustainability, economic resilience, and public health safety.

4 | DISCUSSION

4.1 | Interpretation of Main findings

This review confirms that fish health problems in Ghana are more than just technical issues, but rather high systemic risks to food safety and public health. Aquaculture is a major contributor to national protein needs and rural

household economy; thus, recurrent disease outbreaks, AMR (AMR), and environmental pollution greatly impede national development goals. Beyond negative farm-level impacts, these dimensions intersect with broader one-health implications that connect aquatic ecologies, human health, and regulatory governance.

The importance of these results can be found in the cumulative effect. Taken independently, bacterial diseases, viral epidemics, environmental toxins, and biosecurity lapses may seem like problems we can handle. But if they overwhelm production systems with low surveillance capacity, they can create ripple effects. The Ghanaian aquaculture industry is thus sustainable, not just through increasing production but also through improved systemic resilience.

4.2 | Disease prevalence and pathogen dynamics

The reviewed literature consistently highlights the prevalence of various fish diseases in Ghana, underscoring the substantial threat posed by bacterial, viral, fungal, and parasitic pathogens to the sustainability of aquaculture (Agbeko et al., 2022; Ayiku et al., 2024; Dandi et al., 2024; Diyiye et al., 2022; Kombat et al., 2024). Particularly alarming is the increased prevalence of antibiotic-resistant bacteria, which correlates directly with indiscriminate antibiotic use, inadequate veterinary surveillance and poor law enforcement, and suboptimal management practices (Agbeko, 2020; Agoba et al., 2017; Dandi et al., 2025).

Globally, AMR in aquaculture is increasingly recognized as a transboundary public health issue, with resistant strains documented across Asia, Europe, and Africa. Ghana's case is a reflection of trends observed in other rapidly intensifying aquaculture systems, where expansion often outpaces regulatory capacity. This agreement with global patterns highlights the urgency of transitioning from treatment-based systems to preventive health governance models grounded in responsibility, surveillance, and compliance monitoring.

The proliferation of antibiotic-resistant pathogens like *Aeromonas*, *Pseudomonas*, and *Vibrio* poses severe threats to both fish populations and public health, creating reservoirs of resistance genes transferable across ecological boundaries (Dayie et al., 2024). This finding resonates with global concerns about AMR in aquaculture, underscoring the need for stringent antibiotic governance policies and systematic monitoring.

The emergence of ISKNV has altered the epidemiological landscape of tilapia farming (Alathari et al., 2023; Ayiku et al., 2024). Unlike bacterial infections, viral outbreaks are less responsive to therapeutic intervention and require preventive surveillance and strict adherence to biosecurity measures. The increasing availability of molecular diagnostic tools offers an opportunity to transition toward early detection systems rather than outbreak-driven responses.

Parasitic infestations also emerged as recurrent challenges, often linked to poor water quality and inadequate pond management practices. Ectoparasites, such as monogeneans, significantly reduce productivity by compromising fish growth, increasing morbidity, and increasing susceptibility to secondary infections (Dandi et al., 2024; Kombat et al., 2024). These findings indicate the necessity for integrated pest management (IPM) strategies and routine health assessments as standard practice in aquaculture.

On the international front, countries with advanced aquaculture industries rely heavily on harmonized surveillance, movement controls, and certified hatcheries to reduce viral spread. Ghana's current situation calls for the institution of similar preventive frameworks.

4.3 | Environmental contaminants and fish health risks

Environmental contamination remains a pivotal concern, affecting fish health, aquaculture productivity, and consumer safety. Numerous studies document extensive heavy metal contamination (mercury, lead, cadmium, arsenic), posing chronic toxicological risks to aquatic life and human populations reliant on fish as a primary protein source

(Effah et al., 2021; Kwaansa-Ansah et al., 2019; Sackey et al., 2024). Heavy metal bioaccumulation can significantly impair fish reproduction, immune response, and overall health, underscoring the ecological and public health imperative to address contamination at source levels through improved regulatory frameworks and environmental management practices (Nyarko et al., 2023).

Microplastics have emerged as another critical environmental contaminant, frequently detected in fish tissues across diverse ecosystems (Bruce-Vanderpuije et al., 2025; Nuamah et al., 2023; Pappoe et al., 2022). These findings align with global patterns of microplastic pollution and raise urgent concerns about potential bioaccumulation and toxicities affecting fish physiology and human health via trophic transfer.

Persistent pesticide residues also represent a notable contaminant class, significantly impacting ecosystem health and food safety. Organochlorine pesticides documented by Kuranchie-Mensah et al. (2013) and Fianko et al. (2011) indicate ongoing pesticide pollution from agricultural runoff, exacerbating ecological disruptions and health risks in aquaculture systems. Effective regulatory enforcement, coupled with widespread adoption of IPM in agriculture, could significantly mitigate these impacts.

At a global level, sustainability dialogues in aquaculture are increasingly focused on ecosystem health and climate-related stress. The patterns of contamination in Ghana are indicative of greater challenges throughout the Global South, where agricultural runoff, urbanization, and plastic pollution intersect with food systems. The impact is both ecological and reputational, on export potential and public confidence.

4.4 | Diagnostic capabilities and pathogen surveillance

The capacity for accurate, rapid, and reliable pathogen identification and disease diagnosis remains suboptimal in Ghanaian aquaculture, despite some advancements. Traditional microbiological techniques remain prevalent but are increasingly supplemented by molecular diagnostic methods such as multiplex PCR and eDNA genomic surveillance (Alathari et al., 2023; Diye et al., 2022).

Molecular diagnostic tools have markedly improved pathogen detection accuracy, enabling rapid identification and characterization of emerging pathogens such as ISKNV and antibiotic-resistant bacteria (Agbeko et al., 2022; Ayiku et al., 2024). Despite these advancements, widespread adoption of molecular diagnostics remains limited due to resource constraints, technical capacity gaps, and inadequate laboratory infrastructure. Addressing these limitations through targeted investments in diagnostic facilities, training programs, and knowledge transfer is critical to enhancing capabilities for fish health management.

4.5 | Comparison with global and regional studies

The patterns observed in Ghana are not isolated phenomena but reflect structural transitions occurring across rapidly expanding aquaculture systems worldwide. As aquaculture intensifies to meet growing protein demand, disease emergence, AMR, and environmental degradation increasingly define the sustainability frontier of the sector.

Bacterial pathogens still represent the principal bottleneck to global aquaculture efficiency, and AMR has in recent years developed as a major transboundary health threat (Defoirdt et al., 2011; FAO, 2021). Ghana's experience is evidence of how growth in production without strong stewardship building can speed the emergence of resistance, a pattern also observed in parts of Asia and Latin America during previous stages of aquaculture expansion. In this respect, Ghana is a case in point of a more general trend pertaining to the Global South, where the regulatory environment can be trailing far behind sectoral expansion.

In West Africa, aquaculture systems are experiencing comparable structural pressures. Evidence of antibiotic misuse, weak biosecurity enforcement, and limited disease surveillance capacity in the sub-region suggests that Ghana's challenges are not isolated national issues but a reproduction of broader systemic constraints characteristic

of emerging aquaculture sectors in the region (Adokiya et al., 2025; Agbugui & Abe, 2022; Akindele & Alimba, 2021; Anandkumar et al., 2018). These shared exposures emphasize the need for coordinated regional governance mechanisms, harmonized regulatory standards, and transborder disease monitoring frameworks.

A second axis of global commonality is that of environmental pollution. Heavy metal bioaccumulation, pesticide washout, and microplastic pollution have now become the hallmarks of aquaculture in anthropogenically perturbed watersheds. The contamination in Ghana reflects patterns found in coastal Asia, parts of Latin America, and other West African basins where agricultural intensification, urban expansion, and plastic pollution have converged with aquatic food production. Most importantly, this alignment places Ghana in the global discourse on ecosystem-based aquaculture management and climate-resilient production systems.

The modernization of diagnostic systems in Ghana reflects global moves toward molecular and genomic disease surveillance. However, infrastructure and capacity gaps still distinguish emerging aquaculture producers from high-income countries. Strengthening regional laboratory networks and technical collaboration is essential for aligning with global best practices.

Together, such analogies reflect the fact that Ghana's aquaculture health problems are representative of a more general trajectory of aquaculture development in developing countries. The experience of the country offers important lessons to other new aquaculture systems faced with the challenge of reconciling growth-oriented production efficiency and corporate profits with environmental integrity, public health protection, and regulatory modernisation.

Rather than representing an isolated case study, Ghana is a symbolic aquaculture model at an important early stage of development where near-term strategic decisions on surveillance systems, antimicrobial stewardship, environmental management, and institutional reform will shape long-term sustainability trajectories.

4.6 | Strengths and limitations of this review

The primary strength of this systematic review lies in its comprehensive thematic analysis across diverse aspects of fish health management in Ghana, including pathogens, contaminants, diagnostic practices, management strategies, and regulatory frameworks. Utilizing rigorous PRISMA methodologies, explicit eligibility criteria, structured data extraction, and detailed quality appraisal through MMAT enhance methodological robustness, validity, and replicability.

In spite of the valuable insights synthesized, the evidence base for these findings is subject to important causal and methodological constraints. The predominance of cross-sectional, observational, and laboratory studies does not allow conclusive cause-and-effect associations to be made between environmental stressors, management practices, antimicrobial use, and disease outcomes. Most studies provide associative or prevalence data and not longitudinal or experimental evidence that could indicate causal pathways.

Additionally, diversity in sampling schemes, diagnostic techniques, geographic coverage, and analytical methods hinders the possibility of making comparisons across studies and limits their generalization at a national level. These constraints are inherent to the current state of the research field and not an issue of the present review. However, they do underscore the requirement for standardized surveillance systems, longitudinal epidemiological methods, and an integrated one health.

4.7 | Recommendations for future research directions

Future research should address identified knowledge gaps explicitly:

1. Longitudinal Epidemiological Studies: Undertaking systematic, long-term studies to monitor disease dynamics, contaminant trends, and ecosystem health indicators is crucial for understanding temporal patterns and informing adaptive management strategies.

2. Integrated Approaches to Environmental Health: Investigations examining the cumulative impacts of multiple environmental contaminants (e.g., microplastics combined with heavy metals or pesticides) and their synergistic effects on fish health are necessary to inform holistic environmental management policies.
3. Socio-economic and Behavioral Research: Studying farmer behaviors, decision-making processes, and economic barriers to the adoption of improved management practices can inform targeted policy and capacity-building interventions.
4. Alternative Disease Management Strategies: Research evaluating the efficacy, cost-effectiveness, and scalability of alternative management practices such as probiotics, herbal additives, and vaccination programs in Ghanaian contexts could significantly enhance sustainable disease control methodologies.

5 | CONCLUSIONS

This systematic review has synthesized extensive evidence on fish health in Ghanaian aquaculture, covering critical dimensions such as pathogen prevalence, environmental contamination, diagnostic capacities, fish health management practices, biosecurity measures, and regulatory frameworks from 2010 to 2024. The review underscores the complex interplay among biological, environmental, socio-economic, and governance factors that influence fish health outcomes and aquaculture sustainability in Ghana. Key findings revealed substantial threats posed by bacterial, viral, and parasitic pathogens, with antibiotic-resistant bacteria and emerging viral diseases such as ISKNV representing significant concerns. Environmental contaminants, notably heavy metals, microplastics, and pesticides, persistently compromise fish health and pose broader ecological and public health risks. Diagnostic capabilities, although improving through molecular techniques, remain inadequate, limiting effective disease surveillance and management. Systematic weaknesses identified in fish health management practices and biosecurity measures further exacerbate these threats, compounded by significant knowledge gaps among aquaculture stakeholders and weak regulatory enforcement. Addressing these complex challenges requires integrated, multi-sectoral interventions that focus on regulatory reforms, diagnostic infrastructure development, enhanced surveillance systems, targeted education programs, and strengthened environmental management practices.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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