

Diseases and Integrated Disease Management in Aquaculture

Sumithra TG and Krupesha Sharma SR

Marine Biotechnology, Fish Nutrition and Health Division, ICAR-CMFRI, Kochi

Aquaculture, the fastest-growing food-producing sector, contributes significantly to food security, nutrition, employment, and poverty reduction. However, intensive and semi-intensive farming practices, along with climate change, have increased stress in cultured animals, leading to increased frequency and severity of several infectious and non-infectious diseases. Unscientific management practices, the unethical introduction of exotic animals, and the transboundary movement of fish seeds and adults are other reasons for the introduction of novel pathogens. All these have resulted in serious economic losses, making disease management one of the largest constraints of the aquaculture industry (Elabd et al., 2024). The World Bank reports that aquaculture diseases cause an estimated economic loss of 6 billion USD annually worldwide (Cain, 2022). The economic losses due to diseases in Indian aquaculture are not accurately assessed. However, an earlier survey in Andhra Pradesh, India reported an annual loss of Rs. 40 million due to diseases in aquaculture (Augustine et al., 2020).

In aquaculture, disease occurrence is rarely caused by a single causative agent; instead, disease develops through complex interactions among the host, pathogen, and environmental conditions, which is generally known as the disease triad. Understanding these interactions forms the basis of effective disease prevention and integrated disease management. Accordingly, an Integrated Disease Management (IDM) strategy that includes multiple complementary strategies is required for effective and sustainable disease management in aquaculture. Rather than concentrating on pathogen elimination, IDM preserves the balance in the disease triad, improving the sustainability of aquaculture systems (Yasin et al. 2025).

Aetiology of aquaculture diseases

Any damage that hinders the performance of normal activities of fish, like environmental stress, toxins, pollutants, climate change, malnutrition, and infectious agents, can be termed a disease. The most noticeable sign of disease in any aquaculture system is the presence of weak or dead animals. However, careful and routine observation can identify

the disease before the fish start dying because clinical signs such as anorexia, gasping, surfacing, rubbing against objects, skin discolouration, and lethargy often precede the mass mortality.

Aquatic diseases are broadly classified into infectious and non-infectious categories. Infectious diseases are caused by pathogenic microbes, which include bacteria, viruses, protists, and metazoans. Lafferty et al. (2015) estimated that bacteria, viruses, protists, and metazoans constitute about 25, 34, 19, and 18%, respectively, of the total infectious agents in aquaculture. Conversely, non-infectious diseases in fish are caused by environmental factors, such as changes in water quality, ammonia/nitrite toxicity, low oxygen, fluctuations in water physicochemical characteristics, presence of pollutants and toxins, nutritional deficiencies, or genetic anomalies, and these diseases are not contagious.

Bacterial diseases: The major bacterial pathogens in aquaculture include *Vibrio* spp. (*V. harveyi*, *V. parahaemolyticus*, *V. alginolyticus*, *V. anguillarum*, and *V. vulnificus*), *Aeromonas* spp. (*A. veronii* and *A. hydrophila*), *Streptococcus* spp. (*S. agalactiae* and *S. iniae*), *Photobacterium damsela*, *Tenacibaculum* spp. (*T. maritimum*, *T. soleae*, *T. dicentrarchi*, and *T. discolor*), *Lactococcus garvieae*, *Nocardia seriolae*, *Mycobacterium* spp. (*M. marinum*, *M. fortuitum*, *M. chelonae*, *M. salmoniphilum*, *M. shottsii*, and *M. pseudoshottsii*), *Edwardsiella* spp. (*E. ictaluri* and *E. tarda*), *Renibacterium salmoninarum* and *Flavobacterium columnare* (Austin and Austin 2016; Irshath et al. 2023). Most bacterial pathogens are opportunistic. Accordingly, bacterial disease outbreaks are usually caused by a multitude of stressors like reduced physicochemical and microbiological water quality, poor nutritional status, sudden climate change, increased handling, transport stress, and high stocking density (Burge et al. 2014).

Viral diseases: Viral infections are another concern in aquaculture and can cause high mortality rates in infected populations. Major viral diseases include viral hemorrhagic septicemia (VHS), infectious salmon anaemia (ISA), *Red Sea Bream Iridoviral* disease, viral nervous necrosis or viral encephalopathy and retinopathy (Genus: *Betanodavirus* and Family: *Nodaviridae*), infectious pancreatic necrosis, infectious hematopoietic necrosis, lymphocystis disease virus, Herpes virus infections of fry and fingerling channel catfish, etc (Lorenzen et al., 2019).

Fungal Diseases: Although less common, fungal diseases can cause significant economic losses under high stress or after injuries. The most frequently encountered fungal pathogens in fish include *Aphanomyces* sp. (causes epizootic ulcerative syndrome, EUS), *Saprolegnia*, *Achlya*, *Dermocystidium*, *Branchiomyces*, *Aspergillus*, *Ichthyophonus*, *Lagenidium*, *Haliphthoros*, *Halocrusticida*, *Halioticida*, *Atkinsiella*, *Pythium*, *Fusarium*, *Ochroconis*, *Exophiala*, *Scytalidium*, *Plectosporium*, *Cladosporium* spp. and *Acremonium* (Sadler et al., 2020).

Parasitic Diseases: Parasitic diseases usually do not cause direct loss due to fish mortality, but increase production costs through treatment or reduction in growth and product quality. Amyloodiniosis caused by *Amyloodinium ocellatum*, a parasitic dinoflagellate, is a major threat to marine aquaculture, causing significant mortality in various fish species. *Ichthyophonus hoferi* and *Ichthyophthirius multifiliis* are fish pathogenic protists causing a granulomatous systemic infection, called ichthyophoniasis, which can result in heavy mass mortalities in >80 freshwater and marine species, leading to huge economic losses. *Gyrodactylus salaris*, a parasitic flatworm, affects farmed and wild fish populations (Buchmann & Bresciani, 2006). Other important protozoan diseases of fishes include velvet disease, cryptobiasis, ichthyobodosis (coastiasis), coccidiosis, microsporidiosis, myxosporidiosis, chilodonellosis, and Trichodina infection. Generally, metazoan parasites are less pathogenic in fishes and include various monogeneans, trematodes, cestodes, and crustaceans (Sanil 2020).

Components of integrated disease management

1. **Biosecurity:** Aquaculture disease prevention by decreasing the risk of potential pathogen intrusion into aquaculture facilities and spreading of any infection elsewhere during disease outbreaks can be achieved through 'Biosecurity management' (Ahmed et al. 2024). Biosecurity is defined as a strategic and integrated approach to analyse and manage the risks affecting health and the environment (FAO 2018). While biosecurity targets mitigating disease risks, it provides extra advantages, like increased production, decreased economic losses, enhanced food safety and quality, environmental sustainability, and improved fish health and immunity (Azad et al. 2022), supporting the

sustainability of the aquaculture industry. Hence, implementation of a well-developed biosecurity management plan at the farm level is essential to mitigate the risk of pathogen intrusion or transmission (Ahmed et al. 2024).

The following protocols are part of biosecurity practices in the aquaculture sector.

- Development of quick and sensitive disease diagnostic kits is necessary for early disease diagnosis, thus helping in the implementation of early steps for disease control and management practices.
- Implementation of effective quarantine methods at all the hatcheries to eliminate pathogens. Restrict personnel movement through designated entry points equipped with footbaths, hand sanitisers, and protective clothing.
- Keeping separate equipment for different life-stage units and executing 'all-in, all-out' production systems also help to reduce the risk of pathogen dissemination.
- Screening of all broodstock before initiating the breeding programmes
- Screening of eggs, fry and fingerlings before rearing in the nursery phase
- Regular monitoring of fish health and environmental health in farms
- Maintenance of optimum stocking density and providing nutritionally balanced feeds to avoid stress
- Avoid use of trash fish as the feed.
- Avoid the usage of chemicals and antibiotics in open-water farming systems.
- Periodic sterilisation of biofilters and the entire system
- Strict quarantine measures such as egg disinfection, water treatments, clean feed and disposal of mortalities should be routinely followed. In a study evaluating various aquaculture disinfectants, iodophor and BKC were graded as the most effective disinfectants for aquaculture disinfection programmes (Sumithra et al. 2026a). Similarly, another study by ICAR-CMFRI showed that 20 ppm iodophor for 10 min, 400 ppm H₂O₂ for 10 min, and 40 ppm glutaraldehyde for 5 min were the optimal protocols for marine egg disinfection (Sumithra et al., 2026b).
- Exclusion of vectors and reservoir hosts capable of transmitting pathogens from the aquaculture systems. The fixing of bird netting, perimeter fencing, crab

barriers, screened water inlets, and predator exclusion devices reduces the contact between farmed animals and potential disease reservoirs.

- Proper disposal of dead animals through incineration, deep burial, or composting
2. **Water quality management:** Water is the key medium for pathogen transmission in aquaculture environments, so water quality management is a principal element of integrated disease management. Application of pathogen-free water sources and implementation of water treatment methods like, filtration, sedimentation, ultraviolet irradiation, ozonation, or chlorination before use in production units are part of good water quality management. Chlorination is graded as the best water treatment methodology to prevent disease outbreaks in hatcheries. Apart from this, maintaining optimal physicochemical parameters of water, including temperature, dissolved oxygen, pH, salinity, ammonia, nitrite, and alkalinity, is also required to reduce physiological stress and improve immunity in farmed animals. Regular monitoring of these characteristics aids in the early detection of hostile environmental stresses that predispose animals to disease outbreaks (Boyd and Tucker, 2012).
 3. **Nutrition and immunostimulants:** Optimal nutrition is another key part of IDM in aquaculture, as it directly affects the growth, health, stress tolerance, and immune competence of farmed animals. A balanced feed with optimal levels of proteins, essential fatty acids and amino acids, lipids, vitamins, and minerals improve both innate and adaptive immune responses, decreasing the susceptibility to infectious agents. Apart from the essential nutrients, functional feed additives/immunostimulants have gained significant attention as sustainable alternatives to antibiotics. Nutritional immunostimulants with proven beneficial actions in aquaculture include functional amino acids like glutamate and glutamine, arginine, alanine, tryptophan, methionine, histidine, lysine and taurine, nucleotides, vitamins A, C, D, and E, minerals like calcium, phosphorus, copper, selenium, zinc, iron, chromium, cobalt, and magnesium, etc (Vijayaram et al. 2024). Further, components like β -glucans, carotenoids, mannan oligosaccharides, lectins, chitosan, levamisole, hormones like thyroxine, and plant-derived phytochemicals are also reported to act as efficient

immunostimulants for fish (Wang et al. 2016). Application of immunostimulants during stressful conditions, like transportation, grading, or seasonal environmental changes, can significantly improve disease resistance and survival.

4. **Vaccination:** Vaccination is an effective preventive strategy for controlling infectious diseases in aquaculture. Vaccines can stimulate the fish immune system to develop specific and long-lasting protection against pathogens without contributing to antimicrobial resistance or leaving harmful residues in aquatic products. Even though vaccination has been widely adopted in finfish aquaculture worldwide against vibriosis, furunculosis, streptococcosis, infectious pancreatic necrosis and infectious hematopoietic necrosis, no fish vaccines are commercially available in India.
5. **Probiotics and microbiome management:** The concept of applying probiotics (live beneficial microorganisms) and microbiome management as a disease management strategy in aquaculture is based on their beneficial activities in improving water quality and fish health, altering the microbial community in the aquatic environment and within the GI tract, and promoting non-specific immune response against pathogens (Li et al. 2019). The mode of action of probiotics includes competitive exclusion by colonising in the gut and thus preventing pathogenic bacterial colonisation by producing specific inhibitory compounds, making resources unavailable to pathogens, creating substances that inhibit the quorum sensing system, and increase the host immunity or digestibility of feed by producing digestive enzymes, improving the net availability of critical nutrients, and the host immunity, etc (Rohani et al. 2022).
6. **Surveillance and diagnostics:** Timely and precise disease surveillance, routine health and water quality monitoring, and accurate diagnostics are another principal component of IDM in aquaculture, enabling the implementation of appropriate control measures, minimizing economic losses, preventing the spread of pathogens and ensuring biosecurity in farming systems (WOAH, 2024). Further, any mortality rate surpassing 0.3% per day should be investigated to

identify the aetiology. A daily mortality rate >1.5% should be considered an epizootic, requiring urgent response.

- 7. Responsible antimicrobial use:** Antibiotic treatments have been widely used against bacterial illnesses in aquaculture for several years (Gram et al. 2001). The increasing threat of infectious diseases in intensive and semi-intensive aquaculture practices require an inevitable therapeutic application of antibiotics. However, selective pressures from the usage of antibiotics fuel antimicrobial resistance (AMR). Over the past ten years, the availability of evidence around antimicrobial resistance in aquaculture environments has broadened (Caputo et al. 2023). The World Organisation for Animal Health (2023) and the FAO (2021) highlight that responsible use of antimicrobials in humans, terrestrial and aquatic animals is the principal criterion for AMR preventive measures, thus forming a key component in IDM in aquaculture. Antibiotics should be used only in closed aquaculture facilities, when a bacterial infection has been accurately diagnosed through clinical examination and laboratory testing. Further, use of antimicrobials as a routine prophylactic measure or as a substitute for poor husbandry practices is not recommended. Oxytetracycline, florfenicol, oxolinic acid, sulfadimethoxine/ormetoprim, and enrofloxacin are a few authorised antimicrobials for use in aquaculture (USFDA 2023). Responsible antimicrobial use also includes selecting approved antibiotics by authorised aquaculture professionals based on pathogen identification and antimicrobial susceptibility testing, administering the correct dose for the recommended duration, and strictly observing withdrawal periods before harvest to ensure food safety, etc. Further, following good farming practices, including biosecurity, vaccination, optimal nutrition, water quality management, and regular health surveillance, is required to reduce disease incidence and the need for antimicrobial treatments. Further, proper use of alternatives such as probiotics, prebiotics, and immunostimulants is also required to support disease prevention and reduce antibiotic dependence.

Conclusion

Aquaculture is an indispensable component of the global food production sector.

However, intensified farming practices have increased the occurrence of several diseases, posing major constraints to the sustainability of the sector. Disease outbreaks in aquaculture also threaten biodiversity, ecosystem health, international trade, and consumer safety. Therefore, effective disease management is a central strategy to achieve sustainable aquaculture development. Since aquaculture diseases happen as a result of an imbalance among the host, pathogen, and environment rather than the pathogens alone, an integrated disease management targeting all these three components are necessary. Unlike conventional methodologies that depend on drugs, IDM uses multiple strategies, including biosecurity, water quality management, routine surveillance and early diagnosis, balanced nutrition, immunostimulants, vaccination, probiotics, microbiome management, responsible antimicrobial use, and good husbandry practices to reduce disease risks while reducing environmental impacts. The adoption of the 'One Health' approach, which identifies the interrelation of aquatic environments, animal health, and human health, can further strengthen integrated disease management practices and transform aquaculture into a robust, health-promoting, nutritious food production system. Further, selective breeding for disease-resistant stocks and climate-resilient farming practices can also play a major role in addressing the aquatic disease challenges in future. Briefly, sustainable disease management in aquaculture requires a paradigm shift from reactive treatment to proactive prevention. By merging good aquaculture practices with proper nutrition, early diagnosis, biosecurity, vaccination, and responsible antimicrobial use, IDM offers a holistic pathway toward the long-term sustainability of the global aquaculture industry.