RESEARCH PROGRAM ON Fish

CGIAR

Led by WorldFish

Reducing disease risks in fish through better detection, management and prevention

Tilapia, carp and catfish make up more than a third of world aquaculture production, which is largely undertaken by millions of small- and medium-scale fish farmers in Asia and Africa.[1] The introduction and spread of infectious fish diseases is one of the primary limitations to aquaculture productivity,[2] with direct global losses during production estimated at USD 6 billion per year.[3] Throughout Asia and Africa, farmers commonly experience unexplained mass mortalities and chronic losses of farmed fish that can significantly compromise their livelihoods as well as food and nutrition security.

Fish pathogens spread through poorly documented movement of live fish or when adherence to biosecurity principles[4] is lacking, often where pathogen screening is unavailable. Fish hatcheries are a common center of infection as they are points for fish seed production and distribution. Although the presence of pathogens does not always cause disease, poorly managed aquaculture farms often face greater disease risks. If fish do get sick, pathogens can spread rapidly, leading to fish disease outbreaks and potentially high levels of fish mortality. Left uncontrolled, outbreaks can spread between farms and lead to epidemics.

Global investment in disease detection, management and prevention has been largely directed at high value species like salmon and shrimp. However, trends of aquaculture intensification have led to increasing reports of disease outbreaks in farmed tilapia,[5] carp and catfish.[6] Responding to the need for improved management and prevention of fish disease risks for fish farmers in Asia and Africa, the CGIAR Research Program on Fish Agri-Food Systems (FISH) focused on improving disease detection in breeding centers, hatcheries and farms, and developing fish disease prevention and control strategies for small- and medium-scale fish farmers. Key objectives included the following:

Key messages

- Aquaculture productivity is limited by the introduction and spread of infectious fish diseases, which compromise fish farming livelihoods and food and nutrition security in Asia and Africa.
- Epidemiological tools provide valuable data to understand risk factors for fish disease outbreaks and losses, contributing to improved policies and management measures.
- Using rapid diagnostic tools for early detection of fish pathogens can help hatchery and nursery operators as well as farmers take timely action to reduce the spread of disease.
- Data pipelines emerging from epidemiological and diagnostic tools provide a foundation for new solutions and practical management actions to control fish diseases.
- Implementing better management practices at the farm level will significantly reduce disease-related losses. This requires a major change in integrating and disseminating practical disease control measures in aquaculture extension and vocational training programs.

1. Develop and disseminate data collection and diagnostic tools for fish diseases to support evidence-based decisions on aquatic animal health management.
2. Package health management interventions for tilapia, carp and catfish aquaculture in "better management practices" to improve dissemination and uptake of fish disease control measures.
3. Analyze fish disease and genetic interactions to inform future fish breeding programs, including disease resistance traits.

Improved fish disease detection, management and prevention to increase farm productivity

Epidemiological data helps identify links between risk factors, disease incidence and productivity

The absence of accurate baseline data on fish health and production, farm management practices, and disease occurrence and mortalities hampers disease control efforts by farmers and national authorities. To address this, WorldFish and partners developed an open access epidemiological survey tool for collecting data from different geographies, climates, socioeconomics and farming systems. This data is used to identify risk factors for fish disease susceptibility to inform the development and implementation of evidence-based risk reduction interventions. National stakeholders that adopt this survey tool are contributing to an increasingly rich database on aquatic animal health management, further improving disease management and prevention.

This epidemiological tool is being used in Bangladesh and Egypt and has incorporated data from over 700 farms to date. Wider adoption of the tool to support the development of national aquatic animal health strategies is now underway in Ghana, Kenya and Nigeria, accompanied by training and empowerment of local field teams to use the tool themselves.

Improving early detection of fish pathogens can reduce disease introduction and spread

Routine screening for viral, bacterial and parasitic pathogens is essential for disseminating clean fish broodstock[7] and seed. When applied with oversight from trained health professionals, new diagnostic methods improve the specificity and sensitivity of tilapia lake virus diagnosis (Box 1) and allow rapid in-field detection of *Flavobacterium columnare*, a devastating bacterial pathogen that affects several freshwater fish species around the world.

Portable technologies also have immense potential to detect fish pathogens early. Our "lab-in-a-backpack" is centered on Oxford Nanopore Technologies' portable sequencing tools to rapidly and accurately identify fish pathogens from field samples. To do so includes (i) sampling bacteria from diseased fish, (ii) sequencing bacterial DNA, and (iii) uploading DNA sequences to an online portal where it is (iv) compared to a growing database of reference genomes for bacterial fish pathogens in order to (iv) identify the sampled bacterial pathogens.

The lab-in-a-backpack will enable health specialists and farmers to make timely and effective decisions around disease management. Current work with public and private partners to develop an easily scalable model of the lab-in-a-backpack is expected to be widely available by 2022. When used as part of regular disease screening and outbreak investigations, information from screened bacterial genomic sequences can form a robust, locally owned resource to inform management and prevention measures, potentially including production of autogenous vaccines.

Integrating fish health management in better management practices effectively reduces disease losses

Better health management practices are a set of guidelines for managing fish disease risks and supporting sustainable fish farming. Such practices are intended to help farmers maximize the productivity and profitability of tilapia, carp and catfish in Asia and Africa,[8] and are packaged for widespread adoption by national and regional partners, ideally as part of national aquatic animal health strategies and vocational training programs. Progress is being made with national authorities in Asia and Africa to integrate these resources into national disease management and prevention programs and various extension initiatives.

Tracking antimicrobial resistance to develop suitable interventions

FISH research has also begun to apply the One Health approach to aquaculture to address antimicrobial resistance. Pathogens resistant to antimicrobials can spread through the agri-food system, posing major threats to the health of animals, as well as humans, plants and their shared environment. This is of particular concern in low- and middle-income countries, where there may be less knowledge, regulation and institutional capacity to control antimicrobial use, and there is increasing pressure to intensify food production to meet growing demand.[9]

Systems mapping has been used in Vietnam to characterize antibiotic use and identify hotspots for antibiotic resistance in aquaculture systems. This research provides a foundation to quantify risks associated with antibiotic use along the value chain and identify where interventions are most effective. In Egypt, regular water quality monitoring, improved feed storage conditions and greater access to training are among readily implementable interventions to reduce antibiotic use. Longer-term interventions include improved access to suitable and rapid diagnostics, high quality feeds and genetically improved fish seed, with cost noted as a barrier to implementation. However, innovation and intervention alone are not sufficient to achieve sustained change in antimicrobial use in aquaculture. Evidence from Bangladesh shows that farmer behavior and health management practices are influenced by many social, economic and ecological conditions that may prevent or dissuade the adoption of, for example, disease-free seed.

Box 1. Research innovations allow for better detection, management and prevention of tilapia lake virus

Tilapia lake virus (TiLV) is a highly contagious pathogen that causes high levels of mortality and poses a significant threat to small-scale tilapia farmers. It was discovered in 2014 and has since been reported on three continents: Asia, Africa and South America.[10] For these reasons, our work has prioritized innovation to improve detection, management and prevention of TiLV.

Improved fish pathogen detection and diagnostics is the first step in reducing the introduction and spread of disease. Our new detection method for TiLV is more specific, reducing the incidence of false positive results, and is also more sensitive, as it can detect the virus before initial clinical signs of the disease appear.[11] We are also working on a method to concentrate, detect and quantify TiLV from environmental water samples to aid in early detection of the virus during production and screening of waterbodies destined for production.

Rapid identification of TiLV and inference on its potential origin are essential to continued disease management. We applied Oxford Nanopore Technologies' portable tools to rapidly sequence TiLV from diseased fish within 12 hours of sample collection from farms.[12] Integrating this approach in national evidence-based biosecurity plans will allow aquatic animal health professionals to generate data for epidemiological tracking and management of TiLV and other emerging infectious pathogens in Asia and Africa.

Understanding the route of TiLV transmission to fish informs better biosecurity and screening strategies to reduce and help prevent future disease spread and outbreaks as well as enhance genetic selection for disease resistance. Recent findings around the transmission of TiLV from broodstock to their fertilized eggs[13] stress the importance of screening for disease-free broodstock to produce clean seed. Our tilapia breeding platforms in Asia and Africa now regularly test for TiLV in broodstock to reduce disease risk.

These findings have contributed to a One Health learning platform on antimicrobial resistance, where evidence for interventions is synthesized and evaluated in efforts to strengthen global governance of antimicrobial resistance. This research has also significantly contributed to strengthening partnerships with international institutions and One Health programs to promote a focus on key aquaculture commodities in Asia and Africa.[14]

New data on disease and genetic interactions to inform fish breeding programs

To understand the genetic basis for disease susceptibility and resistance in standard and genetically improved tilapia, WorldFish and partners tracked disease outbreaks in fish with known family histories. By doing this, we were able to characterize the genetic determinants of resistance and discover heritability of resistance traits for viral and parasitic pathogens. These breakthrough findings are guiding the incorporation of disease resistance traits into tilapia breeding programs and will be expanded to carp and catfish in the near future.

Scaling innovations in fish disease detection, management and prevention

FISH research on fish epidemiology, disease diagnostics, better management practices and genetic determinants of disease resistance provides a strong foundation for fish farmers, value chain actors, national authorities and researchers in Asia and Africa to reduce losses caused by disease.

Policy and investment recommendations

Scaling impact from our research requires wider adoption of our tools and findings through a coordinated effort from governments, private companies, development partners, research institutes and stakeholders. Incorporating FISH findings in the development and operationalization of national aquatic animal health strategies has begun in Bangladesh and Egypt. Future policies and investments that will accelerate uptake of the findings include the following:

- further development and dissemination of open access resources, including data and better management practices, to build data pipelines on epidemiology and diagnostics and facilitate equitable uptake of evidence-based disease management and prevention measures by fish farmers, associated value chain actors and national authorities
- capacity development through targeted training of health professionals, small- and medium-scale fish farmers and value chain actors on improved disease surveillance, new diagnostic tools and better management practices for securing tilapia, carp and catfish aquaculture
- investment for scaling the lab-in-a-backpack within the private and public sectors, including component sourcing protocols, developing data protection and privacy measures and providing micro-capital to finance local diagnostic facilities
- incentivizing private companies to incorporate disease and genetics interactions findings into fish breeding programs
- closer collaboration with global agencies to promote evidence-based policies and standards.

Areas for future research

The following research areas are identified as key to helping realize the potential of tilapia, carp and catfish aquaculture for the development of agri-food systems in Asia and Africa:

- better understanding of the contexts, practices, behaviors and drivers that underpin poor fish health management to identify opportunities to implement and further develop research findings
- development of a high throughput multi-pathogen detection system for tilapia, carp and catfish that can efficiently screen seed for many diseases to control the introduction of infectious diseases across Asia and Africa
- formulation of new fish health management solutions, potentially including autogenous vaccines based on local pathogen strains, informed by data generated from the lab-in-a-backpack
- improvement of resources for national agencies and fish farmers to reduce antimicrobial use, including training for environmental and nutritional management and surveillance tools for antimicrobial resistance
- expansion of disease and genetic interaction studies to carps and catfish in effort to produce and disseminate fish with improved resistance to disease.

Health management in small- and medium-scale fish farms in Asia and Africa requires increased focus on species of key importance in domestic markets and for national food and nutrition security. Continued engagement with partners is required to (i) build human capacity for aquatic animal health management, (ii) provide accessible and relevant resources for health professionals, farmers and associated value chain actors, (iii) engage the private sector in scaling disease diagnostic and prevention strategies and tools, and (iv) operationalize national aquatic animal health management strategies across Asia and Africa. These findings, when adopted and scaled, can reach millions of fish farming households with better health management to contribute to broader goals for securing healthy and sustainable aquaculture.

Notes

[1] Food and Agriculture Organization. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome: FAO. https://doi.org/10.4060/ca9229en

[2] Subasinghe RP, Delamare-Debouteville J, Mohan CV and Phillips MJ. 2019. Vulnerabilities in aquatic animal production. *Rev Sci Tech* 38(2):423–36. English, French, Spanish. https://doi.org/10.20506/rst.38.2.2996

[3] Brummett RE, Alvial A, Kibenge F, Forster J, Burgos JM, Ibarra R, St-Hilaire S, Chamberlain GC, Lightner DV, Khoa LV et al. 2014. Reducing disease risk in aquaculture. Agriculture and environmental services discussion paper 9. World Bank report number 88257-GL. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/110681468054563438/Reducing-disease-risk-in-aquaculture

[4] Biosecurity practices are established to minimize the introduction of infectious diseases into a facility (e.g. quarantine), its spread within a facility (e.g. disinfection of equipment) and the risk of infectious agents spreading from a facility to other sites or susceptible species.

[5] Debnath PP, Delamare-Debouteville J, Jansen MD, Phiwsaiya K, Dalia A, Hasan MA, Senapin S, Mohan CV, Dong HT and Rodkhum C. 2020. Two-year surveillance of tilapia lake virus (TiLV) reveals its wide circulation in tilapia farms and hatcheries from multiple districts of Bangladesh. *Journal of Fish Diseases* 43(11):1381–89. https://doi.org/10.1111/jfd.13235

[6] Herbert B, Jones JB, Mohan CV and Perera RP. 2019. Impacts of epizootic ulcerative syndrome on subsistence fisheries and wildlife. *Rev Sci Tech* 38(2):459–75. https://doi.org/10.20506/rst.38.2.2998

[7] Broodstock are mature fish or other aquatic animals used for breeding.

[8] The following resources for tilapia are currently available: major clinical signs, broodstock conditioning and mass spawning in hapas in ponds, illustrated guide for monosex seed production, biosecurity manual for hatchery technicians in Bangladesh (Bangla version), small-scale farming practices and production in Bangladesh, hatcheries in Egypt, tilapia culture in Egypt, genetically improved farmed tilapia in Timor-Leste, and small-scale pond systems in Zambia.

[9] Healey N. 2020. Aquaculture's role in propagating antimicrobial resistance must be addressed. *Nature* 586(7830):S63–S63. https://doi.org/10.1038/d41586-020-02890-5

[10] Jansen MD, Dong HT and Mohan CV. 2019. Tilapia lake virus: A threat to the global tilapia industry? *Reviews in Aquaculture* 11(3):725–39. https://doi.org/10.1111/raq.12254

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[12] Delamare-Debouteville J, Taengphu S, Gan HM, Kayansamruaj P, Debnath PP, Barnes A, Wilkinson S, Kawasaki M, Mohan CV, Senapin S and Dong HT. 2021. Rapid genotyping of tilapia lake virus (TiLV) using Nanopore sequencing. *Journal of Fish Diseases*. https://doi.org/10.1111/jfd.13467

[13] Dong HT, Senapin S, Gangnonngiw W, Nguyen VV, Rodkhum C, Debnath PP, Delamare-Debouteville J and Mohan CV. 2020. Experimental infection reveals transmission of tilapia lake virus (TiLV) from tilapia broodstock to their reproductive organs and fertilized eggs. *Aquaculture* 515:734541. https://doi.org/10.1016/j.aquaculture.2019.734541

[14] As a member of the CGIAR Antimicrobial Resistance Hub and the CGIAR COVID-19 Hub, WorldFish has developed partnerships with international institutions, including the International Livestock Research Institute, International Food Policy Research Institute, International Water Management Institute, University of Exeter, Royal Veterinary College of London, Stockholm Resilience Centre, University of Waterloo, and the Centre for Environment, Fisheries and Aquaculture Science. WorldFish has also been involved with global One Health and antimicrobial resistance programs, including the Fleming Fund Country Grants program, Fleming Fund Regional Grants program, Fleming Fund Fellowships, and the Joint Programming Initiative on Antimicrobial Resistance.

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