



One Health in Aquaculture: A Holistic Approach to Sustainable Aquatic Food Systems

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Aquaculture is the world's fastest-growing food sector and is projected to supply the majority of aquatic dietary protein by 2050. Yet this growth brings profound challenges, including antimicrobial resistance, zoonotic diseases, habitat degradation, and climate change. The One Health framework, recognising the inextricable links between human, animal, and environmental health, offers a transformative lens for sustainable aquaculture governance. This article synthesises current peer-reviewed evidence across these three health dimensions, presents the 15-metric framework of Stentiford et al. (2020, Nature Food), and maps actionable pathways for policy and practice.

Introduction: The Blue Food Revolution

Global fisheries and aquaculture production reached 223.2 million tonnes in 2024, 89% destined for human consumption (FAO, 2024). Aquaculture now accounts for more than half of all seafood globally. Asia supplies 90% of production, with volumes predicted to double by 2050 (Stentiford et al., 2020). With capture fisheries stagnating, farmed aquatic species are indispensable to future food security, providing nutrition for the estimated 733 million people who faced undernourishment in 2023 (FAO et al., 2024).

Yet intensive aquaculture concentrates organisms in confined spaces, creating conditions that favour pathogen amplification, antibiotic misuse, and environmental contamination. The aquatic environment links farmed animals, wild populations, surrounding ecosystems, and human consumers in a web of biological and chemical exchange that cannot be managed through a single-sector lens. The One Health framework, which holds that human, animal, and ecosystem health are fundamentally indivisible, provides the governance architecture this sector urgently needs.

The One Health Framework Applied to Aquaculture

In 2022, WHO, WOA, FAO, and UNEP jointly issued the One Health Joint Plan of Action, targeting zoonotic disease, antimicrobial resistance, food safety, and environmental health as priority tracks (WHO/WOA/FAO/UNEP, 2022). The landmark contribution of Stentiford et al. (2020) in Nature Food translated this into 15 aquaculture-specific success metrics spanning animal health, human health, and environmental integrity from farm-level biosecurity and pathogen control through to gender equity in the supply chain and responsible sourcing of feed ingredients.

A 2025 bibliometric review of 154 publications (Scopus, 2003–2025) confirmed that One Health research in coastal and marine contexts accelerated markedly after 2020, peaking at 37 publications in 2024 yet fewer than 20% explicitly integrated all three health dimensions. This underlines both growing momentum and persistent research gaps.

Table 1. Selected One Health success metrics for sustainable aquaculture (Stentiford et al., 2020)

Health Domain	Example Metric	Policy Implication
Animal Health	Biosecurity & pathogen control at farm level	Mandatory surveillance; species-appropriate welfare standards
Human Health	Food safety monitoring for zoonotic pathogens & AMR	Integrated farm-to-fork inspection; AMR stewardship
Environmental Health	Protection of aquatic biodiversity near farm sites	Spatial planning; effluent treatment; EIA mandates
Human Health	Gender equity in the supply chain	Inclusive social policies; fair wage legislation
Environmental Health	Responsible fishmeal & fish oil sourcing	Feed certification; traceability requirements

Antimicrobial Resistance: A Cross-Cutting Crisis

Antimicrobials in aquaculture, used primarily to treat bacterial infections, have generated resistance genes (ARGs) that now permeate aquatic sediments, fish tissues, and processed seafood. UNEP classifies ARGs among the six most serious novel environmental pollutants (One Health Advances, 2025). Key zoonotic pathogens of concern include *Vibrio* spp., *Aeromonas* spp., *Streptococcus*, and *Edwardsiella* all capable of causing human disease and transmitting resistance genes horizontally across bacterial communities (Milijasevic et al., 2024, Foods). The EU banned routine prophylactic antibiotic use in aquaculture as of January 2022. Beyond Europe, however, stewardship remains poorly institutionalised, particularly in Asia, which produces 90% of farmed seafood. The One Health response requires integrated veterinary-environmental-public health surveillance networks that link farm-level data with national AMR monitoring programmes.

Environmental Health Within Planetary Boundaries

Aquaculture degrades the very ecosystems it depends upon. Uneaten feed and excrement discharge high loads of nitrogen and phosphorus, fuelling algal blooms and oxygen depletion. Scottish salmon farms alone discharged 13,000 t of nitrogen and 1,800 t of phosphorus in a single year (cmbio.io, 2024). Freshwater ecosystems are especially vulnerable 35% of freshwater fish species are classified as threatened (Stentiford et al., 2020) yet they underpin much of the sector's feed supply, broodstock, and seed production. Climate change compounds these pressures through rising temperatures, ocean acidification, and deoxygenation. Recirculating aquaculture systems (RAS) reduce effluent discharge by treating and reusing water within closed loops, but carry significant energy costs that must be weighed holistically. Integrated multi-trophic aquaculture (IMTA) co-cultivating finfish with shellfish and seaweeds converts one species' waste into another's nutrient source, mimicking natural ecosystem function and reducing net environmental load.

Human Health, Nutrition, and Innovative Pathways

A One Health approach extends the human health pillar beyond pathogen control to nutrition security and socio-economic equity. Aquaculture spans subsistence homestead systems that underpin rural food security in low- and middle-income countries, to industrial export enterprises, and governance must address this entire spectrum. Women, in particular, constitute a majority of workers in artisanal processing and aquaculture value chains yet remain systematically underrepresented in policy and undercompensated in practice. Innovation is reshaping risk profiles. Vaccination, which reduced Norwegian salmon antibiotic use from millions of doses in the 1990s to near-negligible levels, is now being extended to shrimp, tilapia, and other key species. Feed innovation is replacing fishmeal with insect meal, single-cell proteins, and algae, reducing pressure on wild marine stocks (Nathanailides, 2025, Animals). Precision aquaculture, deploying AI-driven disease detection

and digital twin monitoring of cage structures, is enabling anticipatory rather than reactive farm management cutting both disease losses and environmental interventions.

Conclusions

The One Health framework is not optional for aquaculture; it is the only governance architecture capable of reconciling the sector's enormous productive potential with its equally significant ecological and public health risks. The 15-metric framework of Stentiford et al. (2020), the WHO-WOAH-FAO-UNEP One Health Joint Plan of Action (2022), and a rapidly growing body of peer-reviewed evidence on AMR, zoonotic disease, and environmental sustainability collectively constitute a compelling case for action.

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