Manuscript ID:
IJRSEAS-2026-030248

OPEN ACCESS

Quick Response Code:

Website: https://eesrd.us

DOI: 10.5281/zenodo.21254736

DOI Link:
https://doi.org/10.5281/zenodo.21254736

Volume: 3

Issue: 2

Pp. 279-284

Month: April

Year: 2026

E-ISSN: 3066-0637

Submitted: 15 Mar. 2026

Revised: 26 Mar. 2026

Accepted: 16 Apr. 2026

Published: 30 Apr. 2026

Address for correspondence:
K. Lavanya, Lecturer in Zoology, Sri YKR&K. Govt. Degree College, Kovur, SPSR. Nellore Dt.
Email:
lavanya.kuppuru@gmail.com

How to cite this article:
K. Lavanya. (2026). A Review on Human Health Risks Triggered by Inappropriate Aquaculture Practices. International Journal of Research Studies on Environment, Earth, and Allied Sciences, 3(2), 279–284.
https://doi.org/10.5281/zenodo.21254736

A Review on Human Health Risks Triggered by Inappropriate Aquaculture Practices

Dr. K. Lavanya
Lecturer in Zoology, Sri YKR&K. Govt. Degree College, Kovur, SPSR. Nellore Dt.

Abstract

Almost half of all seafood consumed worldwide derives from aquaculture, a system of food production that has extended quickly in recent years. Aquatic farming has been considered as the fastest rising food production industry driven by governmental and technological impulsion as compensation for fisheries decline, establishment of new jobs and source of economy are the most important welfares. However, aquaculture raised several issues related to the environmental wellbeing and consumer safety. The impacts of these activities to the environment, through wastes offloads, introduction of alien species, genetic interactions, disease transfer, release of chemicals, use of wild recourses, alterations of coastal habitats and disturbance of wildlife, are analytically considered. Also, the consumer safety issues related to the farming are considered, including generation of antibiotic-resistant microorganisms, contaminants transferred to humans though food chain and other hazards from consumption of aquaculture stuffs. Findings from this review indicate that current aquaculture practices can lead to elevated levels of antibiotic residues, antibiotic-resistant bacteria, persistence of organic pollutants, metals, parasites, and viruses in cultured finfish and shellfish. Additional research is necessary not only to fully understand the human health risks associated with cultured fish versus wild-caught fish but also to develop appropriate interventions that could reduce or prevent these risks.

Keywords: *Aquaculture, Sea food, Antibiotic Residues, Organic Pollutants*

Introduction

The growth of human civilization has been significantly influenced by the process of domesticating plants and animals for the benefit of our species. Agriculture and animal production have been practiced for thousands of years and are seen as essential to the advancement of civilizations. The fish biochemistry and biotechnology approaches to fish nutrition and the health position of fish [Lal J, Vaishnav et al.;2024a: Lal J, Vaishnav et al,2024b]. Aquaculture is the term used to describe the deliberate cultivation of aquatic creatures. While the domestication of certain aquatic creatures has existed for centuries, humans have primarily relied on the fisheries industry to meet their need for seafood and other resources derived from aquatic sources. Aquaculture only recently emerged as a substantial provider of food, accounting for over 50% of the fish and shellfish consumed by humans. It has also become a crucial element in certain area economies [Rogers AJ, 2023; Jana A et al.;2024].

Forecasts anticipate that the world's population will go beyond 9 billion people by 2050 [Syanya FJ,2018; Jennings S et al., 2016]. Consequently, there will be a 50% increase in the demand for fish as a protein source to sustain this growing population. However, diseases during the fish farming process have emerged as a substantial challenge for aquaculture practitioners. These diseases impede the development and sustainability of aquaculture by inflating production costs through fish mortality and the expenses connected with disease treatment [Alfred O, Shaahu A, 2020, Toranzo AE et al., 2005]. Many of these diseases occurs due to deficiencies in essential nutrients. However, the key question remains: do these diseases have adverse effects on the health of consumers who eat farmed fish? The incidence of diseases in aquaculture farms, as reported in Tanzania, not only affects veterinary medicine and disease management but also poses risks to human health and environmental conservation [Mzula A et al.,2021]. In addition to distresses surrounding sustainability and production costs, the aquaculture industry is facing extra challenges due to the emergence of novel diseases such as the Tilapia Lake virus [Mugimba KK et al.,2018].

The Impact of Nutritional Fish Diseases on Human Health:

Effective administration of diseases in aquaculture systems is essential for the sustainable development of aquaculture enterprises [Cole DW et al., 2009]. Among the several diseases and illnesses reported in the aquaculture sector, nutritional diseases and disorders pose significant public health and environmental hazards [Hossain S et al., 2018; Mzula A et al., 2021]. It is therefore essential for all investors in the aquaculture sector to launch clear surveillance plans to minimize cross-contamination and disease spread within the production system.

The recognition of pathogens and the usage of unlicensed veterinary medicines in aquaculture for disease treatment have raised concerns about product rejection in the international export market, impacting fish farmers in countries like India and China [Basavaraja N, 2015; Hernández E et al.,2008]. This has resulted in substantial losses for fish farmers. Additionally, fish feed-derived waste has been found to directly influence the aquaculture environment, posturing challenges to sustainable production and potential health risks for humans [Syanya FJ et al., 2023]. The gathering of fish additives, fish faeces, and other metabolic wastes subsidizes to environmental pollution and poses health hazards [Cole DW et al., 2009; Munguti JM et al.,2014]. These conditions not only cause stress and slow growth in farmed fish but also make them vulnerable to opportunistic diseases that can be detrimental to humans when consumed. Therefore, when articulating fish feeds, careful attention must be given to the levels of vital mineral elements and vitamins to mitigate these risks. Aquaculture can only raise sustainably if the interaction between environmental, social, and economic aspects is well considered [Chua TE,1992]. Sustainable aquaculture has given many coastal and rural communities a enhancement economically, which is especially helpful in places where long-term economic growth is a challenge [Davenport J et al., 2009]. A well-thought-out strategy for rural economic and social development that involves all members of the community is necessary to rectify this disparity. Efficient research, development, monitoring, and incentive programs can help achieve sustainable economic development while also protecting ecosystems and promoting social justice. This approach to watershed and coastal management is essential for conserving ecosystem integrity and striking a balance between human values [Frankic A& Hershner C, 2003; Sahil HS et al., 2022]. Recycling nutrients, or reusing nitrogen, using various polyculture systems may be a more viable and efficient option than managing or treating the effluents linked to conventional, intense monoculture methods. Emerging technologies are frequently created with the aim of lessening certain negative effects caused by current aquaculture systems. However, it is important to note that these technologies may inadvertently transfer the environmental burden by amplifying other significant types of consequences [Salin KR& Arome Ataguba G., 2018].

Antibiotic Use in Aquaculture: Health Risks and Environmental Safety Issues:

Although the use of antibiotics favours boosted production and the extension of the aquaculture industry, they also cart the vices of harmful effects and risk on human and environmental health (Rico et al., 2013). Scores of scientific literatures have tendered confirmatory accounts on the antibiotic accumulation in farmed animal tissues and accumulation in culture and sediments biota, with forthcoming dangerous consequences for environmental and human health (Heuer et al., 2009; Shimizu et al., 2013). The need for consistent and secure drinking water is growing due to the demand for the planet Earth's limited freshwater resources, especially in view of the continued exponential growth of the human population (Xu et al., 2021). The existence and fate of antibiotics in the water environments have recently been the focus of numerous studies conducted around the globe. In the context of antibiotics used in livestock husbandry, the metabolites or degradation products of antibiotics enter the water cycle through the application of manure or slurry to farming used areas, or directly through the excretion of pasture-raised animals on the land, which is then followed by driftage, surface run-off, or leaching into the deeper earth (Caban and Stepnowski, 2021). The aquatic environment may become contaminated with antibiotics from soils. Since the majority of antibiotics are water-soluble, 90% can be eliminated in urine and 75% through animal faces. Aquaculture is another method by which antimicrobial substances used on animals might be discharged into the environment. Aquaculture residuals and resistant bacteria have been reported in recent years (Okeke et al., 2022). However, the effects of sub-inhibitory amounts against non-marine aquatic bacteria are generally unknown. The influence of several antibiotics continuing to be active against bacteria living in wastewater has been described. The use of sewage sludge as wastewater or manure in irrigation may have directly introduced resistant and multi-resistant bacteria into the food chain. Resistant and multi-resistant bacteria have been detected in wastewater and sewage treatment plants. Most of the investigated antibiotic compounds have been persistent under test settings in aquatic systems, whereas only a small number of antibiotics are partially degraded (Zhang et al., 2023)

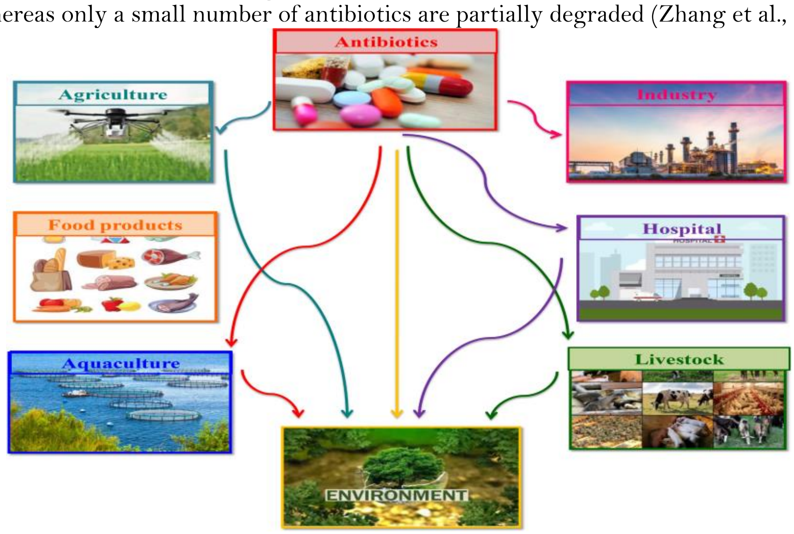

Fig. 3. Entry routes of antibiotics in the environment

The antimicrobial resistance has been sensed in aquaculture worldwide in recent research, which is compelling evidence that this threat to human and environmental health is growing. The culture fish ponds are conceived as the reservoirs of ARGs (antibiotic resistance genes), as the majority of farm used antibiotics (usage either within or outside aquaculture facilities) have been implicated in the development of antimicrobial-resistant microorganisms (Hong et al., 2018; Millanao et al., 2018). In addition, compared to bacteria in areas where there is no aquaculture activity, resident bacteria in commercial aquaculture facilities showed higher ARGs (Gao et al., 2012). The justification is as follows: Long-term exposure to low doses of antibiotics is necessary for the spread of antibiotic resistance to human biological systems; this is suggestive of the potential for resistance in intestinal resident bacteria and suggests that ARGs may spread horizontally by being conjugated with human pathogenic strains (FAO 2005; Tomova et al., 2015). Moreover, Marshall and Levy (2011) and Rico et al. (2013) demonstrated direct transmission of resistant bacterial strains from animals to humans. He et al., (2015) reported the presence of bacteria resistant to antibiotics in aquaculture products in seafood markets of China, hoisting up a major word of consternation in context of health (both of consumers and aquaculture farm workers).

The Puzzling Problem of Multi-Antimicrobial Resistance (Mamr):

The development of multi-antimicrobial resistant (MAMR; Fig. 4) bacterial strains has severely hampered the existing remedial strategies (Chuah et al., 2016; Pham et al., 2018). Due to the blanket and wild usage of drug formulations, the MAMR pattern has been confirmed for two *Aeromonas caviae* HG4 isolates (Rahman et al., 2009); members of Bacilli (Fernandez-Alarcon et al., 2010), *V. parahaemolyticus* and *V. cholerae* (Noorlis et al., 2011); *Vibrio* isolates (Rocha et al., 2016). The presence of antibiotic-resistant *Escherichia coli* (Shah et al., 2014), *Aeromonas*, *Acinetobacter* (Agersø et al., 2007), *Vibrio* (Reboucas et al., 2011; Tuˇsevljak et al., 2013), isolates of *Streptococcus* and *Enterococcus* (Osman et al., 2017), *Salmonella* and *Edwardsiella* (Tuˇsevljak et al., 2013) have also been reported from aquaculture farmed organisms. Also, due to the inherent and intrinsic unions of aquaculture systems with open water bodies, the antibiotic-resistant bacterial strains have been well reported from open water systems (Zhang et al., 2014). The most effective way to stop the spread of MAMRs derived from animal use is to minimize and reduce antibiotic administration in the livestock economy. It has been demonstrated that limiting the use of antibiotics and using other corrective measures can significantly slow the spread of MAMRs in cattle production (Tang et al., 2017). Meanwhile, enhancing animal health through improved livestock management, improved farm hygiene, and the use of a preventative vaccine to fend off animal diseases can aid in reducing the need for antibiotics.

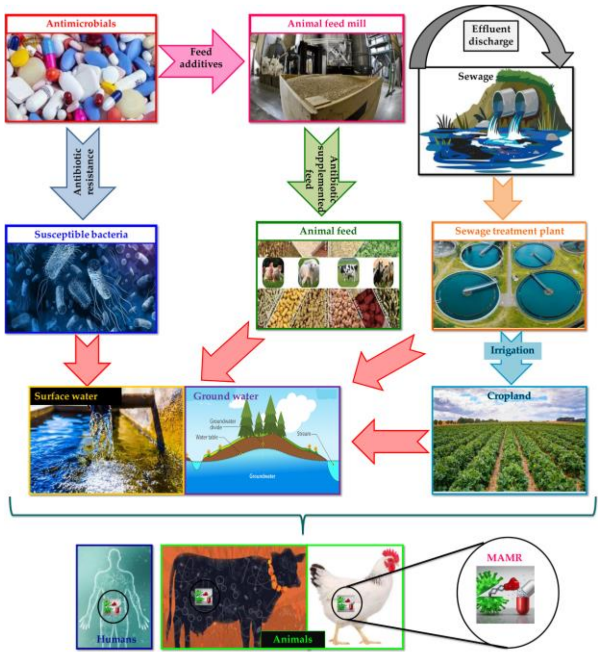

Fig. 4. Environment-to-animal-to-human MAMR transmission pathways in the One Health framework.

Chemical And Biological Contaminants Present In Aquaculture Environments And Their Potential Impacts On Food Safety And Human Health

The intensive aquaculture methods that are practiced in Asia and throughout the world can vary significantly from place to place. However, the majority of aquaculture facilities worldwide rely heavily on the input of formulated feeds and the application of agrochemicals, antibiotics and other inputs, resulting in the presence of many chemical and biological contaminants in aquaculture facilities.

While biological hazards often create a greater short-term risk to consumer health, chemical hazards are generally regarded as the predominant food safety concern [WHO: Geneva, Switzerland, 2009]. Chemical hazards can be broadly classified into two major categories: (i) residues of agricultural chemicals applied during food production, such as pesticides and veterinary pharmaceuticals; (ii) chemical contaminants. The latter may originate from natural biological processes (e.g., mycotoxins), industrial or anthropogenic activities (e.g., polychlorinated biphenyls [PCBs], dioxins, flame retardants, or from the geochemical characteristics of the production environment (e.g., lead, arsenic) [EFSA J. **2025**].

A fundamental distinction between animal foods obtained from terrestrial and aquatic environments lies in the diversity of consumable species. Whereas terrestrial food production is dominated by a limited number of livestock species, aquatic systems provide a much broader range of edible organisms, including numerous fish and shellfish species [FAO,2019]. Although aquaculture increasingly contributes to the global supply of aquatic foods, the majority of production is concentrated among a relatively small number of farmed species [Visciano, P,2024]. Food safety concerns associated with fish are often species-specific. Oily or fatty fish tend to accumulate higher concentrations of lipophilic contaminants such as persistent organic pollutants (POPs), including dioxins, polychlorinated biphenyls (PCBs), brominated flame retardants, and legacy pesticides such as DDT. Toxic metals and metalloids, notably mercury and arsenic, bio accumulate through trophic transfer and are therefore detected at elevated concentrations in predatory fish such as shark, swordfish, and marlin.

Both pelagic (surface-feeding) and benthic (bottom-feeding) fish can accumulate toxins through dietary intake and direct uptake from the surrounding water. However, contamination levels are inclined by local environmental conditions, with benthic species particularly influenced by pollutants present in sediments [Adams et al., 1993]. Shellfish vary markedly from finfish in their physiology and nourishing behaviour. Many species, including oysters, clams, and mussels, are filter feeders that play an ecological role in nitrogen removal by incorporating it into their tissue and shells during growth [Koenig, 2018]. However, filter-feeding shellfish are susceptible to accumulation of polycyclic aromatic hydrocarbons (PAHs), a diverse group of combustion-derived compounds of which several are known to be genotoxic and carcinogenic [Visciano, P,2024]. While most vertebrate species can absorb PAHs, shellfish generally lack this capability, resulting in bioaccumulation. PAHs are also associated with thermally processed foods, such as smoked or charred products, e.g., barbecued foods [Rose et al., 2015].

Marine mammals including cetaceans (e.g., porpoises, dolphins, whales), pinnipeds (e.g., seals, sea lions), sea otters, and sirenians (e.g., manatees, dugongs) inhabit high trophic levels and consequently accumulate substantial body burdens of POPs and other bio accumulative contaminants. These substances can be shifted maternally via placental or lactational pathways [Kibria et al., 2022]. Although such species are primarily studied as indicators of marine pollution, they remain a dietary component in certain human populations.

Conclusion:

The objective of this study was to express the present level of risks to the environment and public health induced by the intensive aquaculture practices. Due to the strong link between human health and fish health, better regulatory frameworks could be a win-win for all. Laws and policies regulating aquaculture need to include the spirit of One Health (achieving optimal health for people, animals and our environment) and ensure that fish health forms the bedrock of sustainable, humane and safe aquaculture practices. Additionally, better monitoring of the entire value-chain, regular farm inspections and surveillance and building the capacity of farmers to ensure prompt disease reporting are needed for mitigation of health risks from aquaculture.

Meanwhile, the blanket use of drug formulations/antibiotics remains high in major producer countries. This emphasizes the call for stern pursuance and enforcement of regulations and policies. Further, meticulous planning, economic investment in research prospects, co-ordination of policies and regulations, and international collaboration are necessary for attaining sustainable aquaculture production and fine-tuned groundwork in production and marketing. The reduction of antibiotic consumption per unit in the manufacture of environmentally friendly and securely ingestible aquatic food should be the overarching goal.

The two-pronged approach of combining pond management and health monitoring is the key for successful aquaculture production. Sustainability of aquaculture depends on the maintenance of a good environment. The understanding of the ecological processes occurring in source water bodies through regular monitoring will help us understand and solve some of the disease issues faced by aqua farmers.

Ultimately, safeguarding the safety and sustainability of aquatic food systems requires a holistic approach that balances nutritional benefits against chemical and biological hazards, integrates environmental and food safety risk assessments, and adapts to evolving challenges posed by climate change and globalisation. By advancing scientific understanding and policy development in these areas, stakeholders can better protect public health and ensure the long-term viability of aquatic food resources

Acknowledgment
I would like to express my sincere gratitude to all those who have contributed to the successful completion of this review study titled "A Review on Human Health Risks Triggered by Inappropriate Aquaculture Practices." I am deeply thankful to my research guide and faculty members for their invaluable guidance, continuous encouragement, and constructive suggestions throughout the preparation of this review. Their expertise and insightful feedback greatly enhanced the quality and scope of this work.

Financial support and sponsorship
Nil.

Conflicts of interest
The authors declare that there are no conflicts of interest regarding the publication of this paper.

References:

1. Adams, S.M.; Brown, A.M.; Goede, R.W. A quantitative health assessment index for rapid evaluation of fish condition in the field. Trans. Am. Fish. Soc. **1993**, 122, 63–73.
2. Alfred O, Shaahu A. An overview on understanding the basic concept of fish diseases in aquaculture; 2020.
3. Basavaraja N. Recent developments in Indian aquaculture. Fish Chim. 2015;34(12):24-8.
4. Caban, M., Stepnowski, P., 2021. How to decrease pharmaceuticals in the environment? A review. Environ. Chem. Lett. 19, 3115–3138.
5. Chuah, L.O., Effarizah, M., Goni, A.M., Rusul, G., 2016. Antibiotic application and emergence of multiple antibiotic resistance (MAR) in global catfish aquaculture. Curr. Environ. Health Rep. 3, 118–127.
6. Chua TE. Coastal aquaculture development and the environment: The role of coastal area management. Marine Pollution Bulletin. 1992, Jan 1;25(1-4):98-103.
7. Cole DW, Cole R, Gaydos SJ, Gray J, Hyland G, Jacques ML, et al. Aquaculture: environmental, toxicological, and health issues. Int J Hyg Environ Health. 2009;212(4):369-77. Available: https://doi.org/10.1016/J.IJHEH.2008.08.003
8. Davenport J, Black KD, Burnell G, Cross T, Culloty S, Ekaratne S, Furness B, Mulcahy M, Thetmeyer H. Aquaculture: the ecological issues. John Wiley & Sons; 2009 Apr 1.
9. FAO, 2005. Responsible Use of Antibiotics in Aquaculture. Food and Agriculture Organization of the United Nations, Rome, Italy. Serrano PHFAO Fisheries Techinical Paper 469.
10. FAO. The State of World Fisheries and Aquaculture; Food and Agriculture Organization of the United Nations: Rome, Italy, 2019.
11. EFSA Scientific Committee; Bennekou, S.H.; Allende, A.; Bearth, A.; Casacuberta, J.; Castle, L.; Coja, T.; Crepet, A.; Halldorsson,T.; Hoogenboom, L.; et al. Guidance on the use of read-across for chemical safety assessment in food and feed. EFSA J. **2025**, 23,e9586.
12. Frankic A, Hershner C. Sustainable aquaculture: Developing the promise of aquaculture. Aquaculture International. 2003, Nov;11:517-30.
13. Gao, P., Mao, D., Luo, Y., Wang, L., Xu, B., Xu, L., 2012. Occurrence of sulfonamide and tetracycline-resistant bacteria and resistance genes in aquaculture environment. Water Res. 46, 2355–2364.
14. He, Y., Tang, Y., Sun, F., Chen, L., 2015. Detection and characterization of integrative and conjugative elements (ICEs)-positive *Vibrio cholerae* isolates from aqua cultured shrimp and the environment in Shanghai, China. Mar. Pollut. Bull. 101, 526–532.
15. Hernández E, Figueroa J, Iregui C. Streptococcosis on a red tilapia, Oreochromis sp., farm: A case study. J Fish Dis. 2009;32(3):247-52. Available: https://doi.org/10.1111/J.1365-2761.2008.00981.
16. Heuer, O.E., Kruse, H., Grave, K., Collignon, P., Karunasagar, I., Angulo, F.J., 2009. Human health consequences of use of antimicrobial agents in aquaculture. Clin. Infect. Dis. 49, 1248–1253
17. Hong, B., Ba, Y., Niu, L., Lou, F., Zhang, Z., Liu, H., et al., 2018. Comprehensive research on antibiotic resistance genes in microbiota of aquatic animals. Front. Microbiol. 9, 1617.
18. Hossain S, Shefat T, Karim MA. Nutritional diseases of fish in aquaculture and their management: A review. Acta Sci Pharm Sci, 2. 2018;5423:2581.
19. Jana A, Kumar A, Lal J, Mandal S, Karmakar S, Bhattacharjee S, Amrutal TM, Singh K, Acharjya NK, Vaishnav A. Exploring the rich diverse: Freshwater fish diversity and bionomics in the Sundarbans, India. Journal of Scientific Research and Reports. 2024, Jun 3;30(6):795–808. Available: https://doi.org/10.9734/jsrr/2024/v30i62096
20. Jennings S, Stentiford GD, Leocadio AM, Jeffery KR, Metcalfe JD, Katsiadaki I, et al. Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy and environment. Fish Fish. 2016;17(4):893-938. Available: https://doi.org/10.1111/FAF.12152
21. Kibria, G.; Nugegoda, D.; Haroon, A.K.Y. Microplastic pollution and contamination of seafood. In Emerging Contaminants and Associated Treatment Technologies; Springer: Berlin/Heidelberg, Germany, 2022; pp. 277–322.
22. Koenig, E. Can Clams and Oysters Help Clean UpWaterways? Woods Hole Oceanographic Institution. 2018. Available online: https://www.whoi.edu/oceanus/feature/can-clams-and-oysters-help-clean-up-waterways/
23. Lal J, Vaishnav A, Chandravanshi S, Kashyap N, Jaiswar R, Kumar A, Verma DK, Jayaswal R, Acharjya AJ. Unraveling the secrets of fish biochemistry: A comprehensive review of recent advances; 2024a.
24. Lal J, Vaishnav A, Chandravanshi S, Kashyap N, Ramasre JR, Kumar A, Jana A, Verma DK, Jayaswal R, Acharjya NK. Revolutionizing fish biotechnology:
25. Marshall, B.M., Levy, S.B., 2011. Food animals and antimicrobials: impacts on human health. Clin. Microbiol. Rev. 24, 718–733.
26. Millanao, A.R., Barrientos-Schaffeld, C., Siegel-Tike, C.D., Tomova, A., Ivanova, L., Godfrey, H.P., et al., 2018. Antimicrobial resistance in Chile and the one health paradigm: dealing with threats to human and veterinary health resulting from antimicrobial use in Salmon aquaculture and the clinic. Rev. Chil. Infectol. 35, 299–303.
27. Mugimba KK, Chengula AA, Wamala S, Mwega ED, Kasanga CJ, Byarugaba DK, et al. Detection of tilapia lake virus (TiLV) infection by PCR in farmed and wild Nile tilapia (*Oreochromis niloticus*) from Lake Victoria. J Fish Dis. 2018;41(8):1181-9. Available: https://doi.org/10.1111/JFD.12790

28. Munguti JM, Kim JD, Ogello EO. An overview of Kenyan aquaculture: Current status, challenges, and opportunities for future development. Fish Aquat Sci. 2014;17(1):1-11. Available: https://doi.org/10.5657/FAS.2014.0001
29. Mzula A, Wambura PN, Mdegela RH, Shirima GM. Present status of aquaculture and the challenge of bacterial diseases in freshwater farmed fish in Tanzania; A call for sustainable strategies. Aquacult Fish. 2021;6(3):247-53.
30. Noorlis, A., Ghazali, F.M., Cheah, Y.K., Tuan Zainazor, T.C., Wong, W.C., Tunung, R., et al., 2011. Antibiotic resistance and biosafety of *Vibriocholerae* and *Vibrio parahaemolyticus* from freshwater fish at retail level. Int. Food Res. J. 18, 1523–1530.
31. Okeke, E.S., Chukwudozie, K.I., Nyaruaba, R., et al., 2022. Antibiotic resistance in aquaculture and aquatic organisms: a review of current nanotechnology applications for sustainable management. Environ. Sci. Pollut. Res. 29, 69241–69274.
32. Pham, T.T.H., Rossi, P., Dinh, H.D.K., Pham, N.T.A., Tran, P.A., Ho, T., et al., 2018. Analysis of antibiotic multi-resistant bacteria and resistance genes in the effluent of an intensive shrimp farm (Long An, Vietnam). J. Environ. Manage. 214, 149–156.
33. Phu, T.M., Phuong, N.T., Dung, T.T., Hai, D.M., Son, V.N., Rico, A., et al., 2016.
34. Rahman, M., Huys, G., Kühn, I., Rahman, M., M¨ollby, R., 2009. Prevalence and transmission of antimicrobial resistance among *Aeromonas* populations from a duckweed aquaculture based hospital sewage water recycling system in Bangladesh. Antonie van Leeuwenhoek. Int. J. Gen. Mol. Microbiol. 96, 313–321
35. Rico, A., Phu, T.M., Satapornvanit, K., Min, J., Shahabuddin, A.M., Henriksson, P.J.G., et al., 2013. Use of veterinary medicines, feed additives and probiotics in four major internationally traded aquaculture species farmed in Asia. Aquaculture 412, 231–243.
36. Rogers AJ. Aquaculture in the ancient world: Ecosystem engineering, domesticated landscapes, and the first Blue Revolution. Journal of Archaeological Research. 2023, Sep;12:1-65.
37. Rose, M.; Holland, J.; Dowding, A.; Petch, S.; White, S.; Fernandes, A.; Mortimer, D. Investigation of the formation of PAHs in foods prepared in the home to determine the effects of frying, grilling, barbe-cuing, toasting and roasting. Food Chem. Toxicol. **2015**, 78, 1–9.
38. Syanya FJ. An investigation on causal elements for project sustainability among selected nongovernmental organizations in the education sector: A case Ofnairobi County. IOSR J Humanit Soc Sci (IOSR-JHSS. 2018;23(1):63-105. Available:https://doi.org/10.9790/0837-23010263105
39. Syanya FJ, Mathia WM, Harikrishnan M. Quality and safety concerns of farmed tilapia fish during freezing and frozen storage: Review [review]. Asian Food Sci J. 2023b;22(6):40-58. Available:https://doi.org/10.9734/AFSJ/2023/V22I6641
40. Sahil HS, Nayak SK, Kumar S, Sudhan C, Kashyap DK, Gautam P, Lal J, Singh SK. Length-weight relationship of small cyprinid fish: Securicula gora (Hamilton, 1822) From River Burhi Gandak, Bihar, India; 2022.
41. Salin KR, Arome Ataguba G. Aquaculture and the environment: Towards sustainability. Sustainable Aquaculture. 2018;1-62.
42. Tang, K.L., Caffrey, N.P., Nobrega, D.B., Cork, S.C., Ronksley, P.E., Barkema, H.W., Polachek, A.J., Ganshorn, H., Sharma, N., Kellner, J.D., Ghali, W.A., 2017. Restricting the use of antibiotics in food-producing animals and its associations with antibiotic resistance in food-producing animals and human beings: A systematic review and meta-analysis. Lancet Planet Health 1 (8), e316–e327. https://doi.org/ 10.1016/S2542-5196(17)30141-9.
43. Tijo Cherian, Chinnasamy Ragavendran, Smitha Vijayan a, Sini Kurien a, Willie J.G. M. Peijnenburg, A review on the fate, human health and environmental impacts, as well as regulation of antibiotics used in aquaculture, Environmental Advances 13 (2023) 100411
44. Tomova, A., Ivanova, L., Buschmann, A.H., Rioseco, M.L., Kalsi, R.K., Godfrey, H.P., et al., 2015. Antimicrobial resistance genes in marine bacteria and human uropathogenic *Escherichia coli* from a region of intensive aquaculture. Environ. Microbiol. Rep. 7, 803–809.
45. Toranzo AE, Magariños B, Romalde JL. A review of the main bacterial fish diseases in mariculturesystems. Aquaculture.2005;246(1-4):37-61. Available: https://doi.org/10.1016/j.aquaculture.2005.01.002
46. Tuˇsevljak, N., Dutil, L., Rajíc, A., Uhland, F., McClure, C., St-Hilaire, S., 2013. Antimicrobial use and resistance in aquaculture: findings of a globally administered survey of aquaculture-allied professionals. Zoonoses Public Health 60, 426–436.
47. Visciano, P. Environmental contaminants in fish products: Food safety issues and remediation strategies. Foods **2024**, 13, 3511.
48. World Health Organization. Principles and Methods for the Risk Assessment of Chemicals in Food; Environmental Health Criteria 240; WHO: Geneva, Switzerland, 2009.
49. Xu, L., Zhang, He, Xiong, P., Zhu, Q., Liao, C., Jiang, G., 2021. Occurrence, fate, and risk assessment of typical tetracycline antibiotics in the aquatic environment: A review. Sci. Total Environ. 753, 141975.
50. Zhang, Q., Jia, A., Wan, Y., Liu, H., Wang, K., Peng, H., et al., 2014. Occurrences of three classes of antibiotics in a natural river basin: association with antibiotic-resistant *Escherichia coli.* Environ. Sci. Technol. 48, 14317–14325.
51. Zhang, J., Zhang, X., Zhou, Y., Han, Q., Wang, X., Song, C., Wang, S., Zhao, S., 2023. Occurrence, distribution and risk assessment of antibiotics at various aquaculture stages in typical aquaculture areas surrounding the Yellow Sea. J. Environ. Sci. 126, 621–632.