E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2025; 13(3): 13-17

www.fisheriesjournal.com
Received: 03-02-2025
Accepted: 08-03-2025

Edwin Baluku
National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Barirega Akankwasah
National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Dennis Twinomujuni
National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Adson Tumwebaze
National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Francis Sabino Ogwal
National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Angelina Ngonzebwa
National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Richard Komakech
Ph.D., National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Corresponding Author:
Richard Komakech
Ph.D., National Environment Management Authority. P.O Box 22255, Kampala, Uganda

Environmental impacts of cage fish farming: A review

Edwin Baluku, Barirega Akankwasah, Dennis Twinomujuni, Adson Tumwebaze, Francis Sabino Ogwal, Angelina Ngonzebwa and Richard Komakech

DOI: https://www.doi.org/10.22271/fish.2025.v13.i3a.3071

Abstract
As global fish consumption rises, driven by population growth, aquaculture has emerged as a vital solution to meet fish demand, particularly with the declining capture fisheries and constrained terrestrial food production. A narrative literature review was conducted, focusing on the impact of cage fish farming on the environment, and the economic contributions of aquaculture. While cage farming offers economic opportunities and ensures food security, it also raises serious environmental concerns, including, water pollution, eutrophication, disruptions to water transport and aquatic biodiversity and the risk of disease transmission to native fish populations. The expansion of aquaculture has led to conflicts with traditional fishing practices and environmental degradation. This review analyses literature, focusing on the balance between cage fish farming development and environmental sustainability, emphasizing the need for effective management practices to mitigate negative impacts of cage fish farming and ensure long term health of aquatic ecosystems.

Keywords: Aquaculture, cage fish farming, fish, environment, aquatic environment

Introduction

Cage fish farming is the raising of fish in a confined structure that is placed in an existing water body. (Mensah, 2018) [3]. Globally, fish production in natural environments has been declining and this has been attributed to overfishing, use of illegal fishing methods and pollution of water bodies. In an effort to achieve the United Nations sustainable development goal SDG 14, cage fish farming has been adopted to replenish the dwindling fish stocks to meet global fish demands (FAO, 2018) [11].

Capture fisheries production is unlikely to rise, and terrestrial food production is constrained by the availability of freshwater and arable land, setting a ceiling on global food production (Holmer, 2010) [8]. Aquaculture plays important role in satisfying the global demand for fish, as fish stocks are being overfished (Karikari *et al* 2021) [1]. This demand is anticipated to grow due to the rising global population, along with improvements in income levels and urbanization. Aquaculture is the fastest expanding sector globally and is widely regarded as a viable practice for bridging the growing gap between the demand for fish and its supply (Njiru *et al*., 2019) [4]. In 2022, global fisheries and aquaculture production hit a record 223.2 million tonnes, valued at USD 472 billion, providing an estimated 20.7 kg of aquatic animal foods per capita (FAO, 2024). In 2022, global production of aquaculture accounted for 50.9% of the total output from both capture and aquaculture, an increase from 49.4% in 2020. In many countries, particularly leading aquaculture producers like China, India, Vietnam, and Bangladesh, aquaculture production has surpassed capture fisheries for several years. This trend is also seen in smaller producers with limited capture fishery resources, such as Uganda, Jordan and Lesotho.

Despite the rapid growth of the cage fish farming sector, many concerns have been raised regarding the environmental effects of cage culture, specifically on its impact on water quality and the biotic composition of water bodies (Degefu *et al*, 2011) [22]. Cage fish farming relies on natural water sources and natural food chains and its expansion could negatively impact water quality (Nabirye *et al*., 2016) [2]. In addition, fish cage farming releases significant quantities of nutrient rich waste, including feacal matter, leftover feed, and metabolic byproducts, into the water in high concentrations severely impacting water quality, both directly and indirectly (Karikari *et al*., 2021) [1]. Therefore, a thorough understanding of the impacts of cage fish farming on the aquatic ecosystems is essential for sustainable utilization of water resources.

Methodology

A narrative literature search was conducted following a modified method previously used by Komakech and Kang, (2019) [23] and Baluku *et al*, (2024) [24] across academic databases, including Google Scholar, Scopus, and Web of Science, using keywords such as "cage fish farming" and "environmental impacts of cage fish farming." The inclusion criteria focused on peer-reviewed articles published between 2010 and 2025. The collected literature was categorized into key themes: socio-economic benefits and ecological impacts, facilitating qualitative analysis to identify trends and gaps. The findings from the literature review were synthesized to provide a comprehensive overview, informing evidence based information for sustainable practices.

Socio-economic impacts of Cage Fish Farming

Fish cage culture has been identified as a strategic practice with the potential to increase fish production (Mbowa *et al.*, 2017) [15]. In sub-Saharan Africa forexample, Uganda holds the second position in aquaculture production in Sub-Saharan Africa, growing substantially from 800 tons in 2006 to 138,558 tons in 2021 (Harikrishnan *et al.*, 2024) [19]. This growth is largely credited to Nile tilapia (*Oreochromis niloticus*), a widely farmed species that accounts for around 49% of the country's total annual aquaculture output. Kenya's fisheries sector contributes valuable foreign exchange to the government, accounting for approximately 0.5% of the country's earnings (Mwamburi *et al*., 2021) [18]. Unlike Uganda and Kenya, where fish farming is well developed, Tanzania's aquaculture sector remains largely small-scale, contributing only 4% to the country's total fish production (Harikrishnan *et al*., 2024) [19].

Globally, a study by FAO (2024) showed that approximately 61.8 million individuals were employed as full-time, part-time, occasional, or unspecified workers in the primary sector of commercial fisheries and aquaculture in 2022, accounting for 36% of the global work force. Another study by Guloba *et al*., (2023) [17] showed that Employment opportunities in the fishing sector on Lake Victoria had significantly expanded, rising from 34,889 jobs in 2000 to over 60,000 by 2020, highlighting the sector's growing importance for livelihoods in the region

With declining catches from capture fisheries, cage fish farming has emerged as a vital solution to boost fish production, meet local market demands, and ensure food security (Okechi *et al*., 2022; Naylor *et al*., 2021) [5, 6]. This aquaculture method allows for increased fish yields in controlled environments, providing a steady supply of fish that supports local economies and livelihoods. In a study done by Mbowa *et al*., (2017) [15] the findings indicated that innovative technologies like floating cage culture were significantly more productive than traditional capture fisheries with farmers utilizing floating cage technology generating 12 times the annual tonnage compared to those engaged in capture fishing.

The economic advantages of cage farming can reduce reliance on capture fisheries. Cage fishing enhances food availability and affordability, especially in communities that depend heavily on fish as a primary protein source. Cage culture is a high profitable aquaculture system used in various regions globally, including Europe, North America, Latin America, and Asia and if managed properly, it holds significant potential to boost economic growth in the Lake Victoria area. (Njiru *et al.*, 2019) [4].

Poorly planned cage farms create conflicts with other existing activities, such as capture fishing, recreational activities, conservation efforts and water extraction for domestic and industrial use. In addition, floating cages that protrude above the water surface interfere with water transport on water bodies (Fig 1). The likelihood of these challenges is heightened by the establishment of cage aquaculture enterprises that often do not fully adhere to best management practices (Musinguzi *et al*., 2019) [16].

Fig 1: Floating fish cages on Lake Victoria

Effects of Cage Fish Farming on Water Quality

Whereas cage fish farming offers economic benefits, it also raises significant environmental concerns. Like other animal production sectors, aquaculture produces waste, and managing the waste from fish farming is both challenging and costly, as it disintegrates and becomes diluted in the culture water. Due to waste generated from uneaten fish feed and faecal matter, Cage farms lead to increased nutrient loading in surrounding waters. This nutrient overload results in eutrophication, characterized by excessive growth of algae, increased turbidity, and in severe cases, anoxia (Okechi *et al.*, 2022) [5]. Increased turbidity reduces light penetration, which negatively impacts phytoplankton production and may hinder the photosynthesis of benthic aquatic vegetation (Price *et al.*, 2015) [10]. In addition, anoxia, the complete absence of oxygen results in the death of aquatic organisms, disrupting ecosystems and causing loss of biodiversity (Riedel *et al* 2014) [9].

In addition, a study done by Zhang *et al*., (2020) [7] indicates that a substantial portion of nitrogen and phosphorus from fish feeds remains unutilized by fish, resulting in higher nutrient concentrations in waters surrounding cage farms compared to natural aquatic ecosystems. This nutrient enrichment often promotes the growth of invasive species such as water hyacinth (*Eichhornia crassipes*), which can further disrupt local ecosystems. While the discharge of dissolved nitrogen and phosphorus from fish farms may be challenging to quantify, the secondary impacts associated with nutrient enrichment are of greater concern, as they fundamentally alter aquatic habitats (Price *et al.*, 2015) [10].

Waste products from cage fish farming result in spread of pathogens and parasites, infecting fish and other aquatic organisms (Azizpour *et al.*, 2025) [25]. Furthermore, fish waste and unutilized fish feed rich in protein elevate ammonia levels near the cages (Fig: 2). Excessive ammonia is highly toxic to fish, with harmful concentrations of unionized ammonia for tilapia ranging from 0.6 to 2.0 mg/L. Even at concentrations as low as 0.08 mg/L, unionized ammonia can reduce the appetite of tilapia, while prolonged exposure to levels as low as 0.2 mg/L can result in fish fatalities (Njiru *et al.*, 2019) [4]. Metallic components on cage fish farming systems corrode and generate trace metals such as copper and zinc that accumulate in sediments below fish cages over time (Kalantzi *et al.*, 2013) [26].

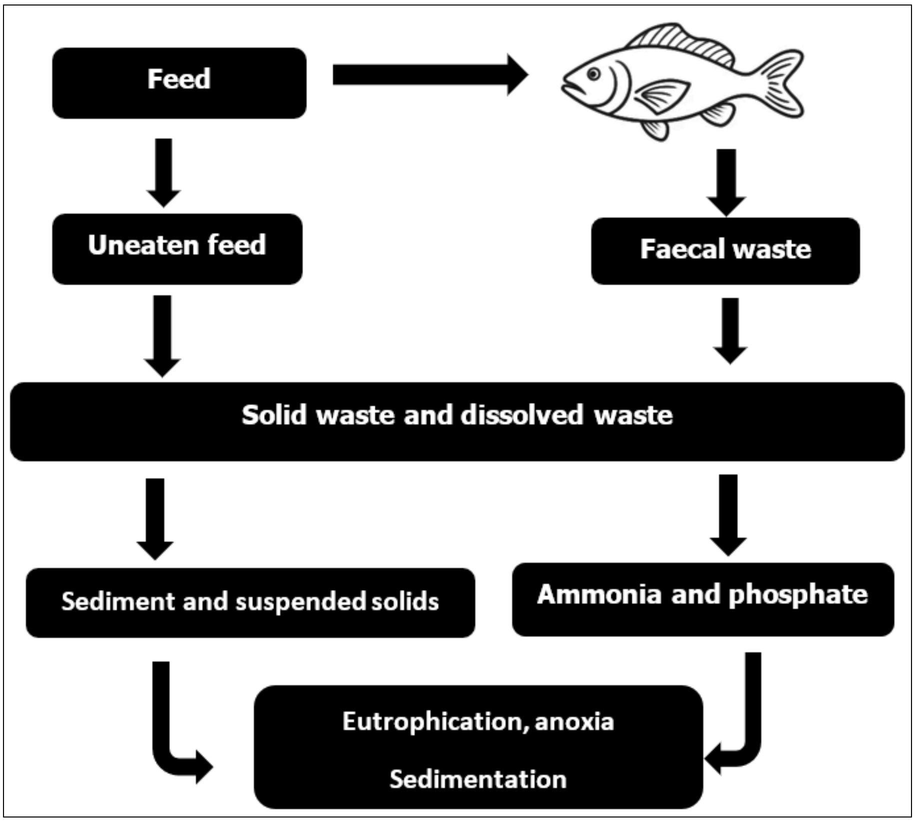

Fig 2: schematic generation of aquaculture waste

Effects of cage fish farming on aquatic organisms

The rapid expansion of aquaculture has raised concerns about a rising number of escapees entering natural ecosystems. Increased Breakdown of aquaculture systems and cages in open waters of have led to unintentional release of predatory fish such as North African catfish into the lakes (Harikrishnan *et al*., 2024) [19]. For example, Fishermen along rivers and Lake Victoria wetlands have reported cases of catfish disrupting local ecosystems by preying on native fish species while also creating competition for food and resources between native fish and non-native fish. The invasive nature of North African catfish highlights its detrimental impact on indigenous aquatic fauna.

In addition, when farmed fish escape into the wild, they interact with native fish populations, they potentially introduce diseases and parasites that the wild fish have not been exposed to. This can disrupt the balance of the ecosystem, as native species may lack the immunity to these new pathogens, leading to increased mortality rates. (Kashindye *et al.*, 2015) [14].

Further, cage fish farming facilitates rearing of large numbers of fish in a small confined area. This overcrowding increases oxygen demand by fish, resulting in reduced oxygen levels in their rearing environment (Mrcelic and Sliskovic, 2010) [20].

Cage fish farms produce and release wastes rich in nitrogen and phosphorus into the water column and bottom sediments. High nutrient inputs lead to eutrophic conditions characterized by phytoplankton blooms, high ammonia built up, high nitrite, low dissolved oxygen and high turbidity. This increased nutrient enrichment decreases the species diversity of benthic macro-invertebrate communities. In addition, studies have showed that cage fish farming can cause localized and significant changes on macro-invertebrate community structure as manifested in the observed reduction of species diversity and increased abundance of pollution-tolerant forms such as *Chironomus sp.* and *Melanonids tuberculate* (Nabirye *et al*., 2016) [2]. However, when well-managed, cage farms can also serve as refugia from fishing pressures and natural predation. They can stimulate a periphyton-based benthic food web, which may help restore and sustain aquatic biodiversity while supporting regional food security (Okechi *et al*., 2022) [5].

Conclusion

Cage fish farming offers significant economic opportunities, particularly as global demand for fish continues to rise. It has the potential to enhance fish production improve food security, improve local livelihoods and foreign exchange earnings. However, this review showed that cage fish farming presents a number of environmental challenges including, eutrophication, disease transmission, alterations in aquatic biota, and degraded water quality. These issues threaten the ecological balance of aquatic ecosystems, which is important for the communities that depend on it. Therefore, too fully harness the potential of cage fish farming as a sustainable aquaculture strategy, it is important that future developments integrate advanced waste management and environmental monitoring systems. In doing so, the aquaculture sector can contribute not only to economic growth but also to the long-term sustainability and resilience of aquatic ecosystems.

Declaration of Competing Interests

The authors confirm that they have no known conflicts of interest or personal relationships that could have influenced the findings presented in this review paper.

Author contributions

E. Baluku is the author of the review, B. Akankwasah, D. Twinomujuni, A. Tumwebaze, and F. S. Ogwal, A. Ngonzebwa[1] edited the work while R. Komakech is the corresponding author.

Declaration of competing interest

The authors declare that they have no conflicting financial interests or personal relationships that could potentially influence the findings presented in this paper.

References

1. Karikari AY, Asmah R, Anku WW, Amisah S, Trevor TC, Lindsay RG, *et al*. Assessment of Cage Fish Farm Impacts On Physico-Chemical Parameters of The Volta Lake In Ghana. Journal Of Fisheries And Coastal Management. 2021;3(2):22-35. DOI: 10.5455/Jfcom.20210303023816.
2. Nabirye H, Mwebaza-Ndawula L, Bugenyi FW, Muyodi FJ. The Evaluation Of Cage Fish Farming Effects On Water Quality Using Selected Benthic Macro-Invertebrate Community Parameters In The Napoleon Gulf, Northern Lake Victoria. International Journal Of Fisheries And Aquatic Studies. 2016;4(1):42-50.
3. Mensah VF, Annang TY, Ofori BD. Environmental And Socioeconomic Impact Of Cage Aquaculture At Kpeve Tornu Section Of The Volta Lake, Ghana. Bonorowo Wetlands. 2018;8(2):84-95. DOI: 10.13057/Bonorowo/W080205.
4. Njiru JM, Aura CM, Okechi JK. Cage fish culture in Lake Victoria: A boon or a disaster in waiting? Fish Manag Ecol. 2019 Nov;26(6):426-434. DOI: 10.1111/fme.12283.
5. Okechi JK, Peoples N, Nyamweya CS, Glaser S, Kaufman L. The ecological health of Lake Victoria (Kenya) in the face of growing cage aquaculture. Conserv Sci Pract. 2022 Nov;4(11):e12826. DOI: 10.1111/csp2.12826.
6. Naylor RL, Hardy RW, Buschmann AH, Bush SR, Cao L, Klinger DH, *et al*. A 20-year retrospective review of global aquaculture. Nature. 2021 Mar 25;591(7850):551-563.
7. Zhang X, Zhang Y, Zhang Q, Liu P, Guo R, Jin S, *et al*. Evaluation and Analysis of Water Quality of Marine Aquaculture Area. Int J Environ Res Public Health. 2020 Feb 18;17(4):1446. DOI: 10.3300/ijerph17041446.
8. Holmer M. Environmental issues of fish farming in offshore waters: perspectives, concerns and research needs. Aquacult Environ Interact. 2010 Jul 15;1:57-70. DOI: 10.3354/aei00007.
9. Riedel B, Pados T, Pretterebner K, Schiemer L, Steckbauer A, Haselmair A, *et al*. Effect of hypoxia and anoxia on invertebrate behaviour: ecological perspectives from species to community level. Biogeosciences. 2014 Feb 28;11(5):1491-1518. DOI: 10.5194/bg-11-1491-2014.
10. Price C, Black KD, Hargrave BT, Morris JA Jr. Marine cage culture and the environment: effects on water quality and primary production. Aquacult Environ Interact. 2015 Sep 17;6:151-174. DOI: 10.3354/aei00122.
11. FAO. The state of world fisheries and aquaculture 2018. Rome, Italy: FAO; c2018.
12. Munguti JM, Musa S, Orina PS, Kyule DN, Opiyo MA, Charo-Karisa H, *et al*. An overview of current status of Kenyan fish feed industry and feed management practices, challenges and opportunities. International Journal of Fisheries and Aquatic Studies. 2014;1(6):128-137.
13. Amirkolaie AK. Reduction in the environmental impact of waste discharged by fish farms through feed and feeding. Aquacult Environ Interact. 2011 Apr 14;3:19-26. DOI: 10.1111/j.1753-5131.2010.01040.x.
14. Kashindye BB, Nsinda P, Kayanda R, Ngupula GW, Mashafi CA, Ezekiel CN, *et al*. Environmental impacts of cage culture in Lake Victoria: the case of Shirati Bay-Sota, Tanzania. Springerplus. 2015 Aug 20;4:475. DOI: 10.1186/s40064-015-1241-y.
15. Mbowa S, Odokonyero T, Munyaho AT. Harnessing Floating Cage Technology To Increase Fish Production In Uganda. Research Series No. 138. Kampala, Uganda: Economic Policy Research Centre (Eprc); c2017.
16. Musinguzi L, Lugya J, Rwezawula P, Kamya A, Nuwahereza C, Halafo J, *et al*. The extent of cage aquaculture, adherence to best practices and reflections for sustainable aquaculture on African inland waters. J Great Lakes Res. 2019 Dec;45(6):1219-1229. DOI: 10.1016/j.jglr.2019.09.011.
17. Guloba MM, Birabwa EA, Mbowa S, Kahunde R. Enhancing Agro-Industry For Productive And Decent Work For Youth And Women In Uganda: The Case For Fish And Cotton Value Chains. Research Report No. 23. Kampala, Uganda: Economic Policy Research Centre (Eprc); c2023.
18. Mwamburi J, Yongo E, Omwega R, Owiti H. Fish cage culture in Lake Victoria (Kenya): Fisher community perspectives on the impacts and benefits for better sustainable management. Int J Fish Aquat Stud. 2021;9(4):23-29. DOI: 10.22271/fish.2021.v9.i4a.2518.
19. Harikrishnan M, Syanya FJ, Khanna ARN, Mumina P, Mathia WM. Ecological implications of unintentional aquaculture escapees: an overview of risks, remediation strategies and knowledge gaps in the aquaculture sector of India and riparian East African countries. Marine and Fishery Sciences. 2024;37(4):1049-1064. DOI: 10.47193/mafi.3742024010709.
20. Jelic Mrcelic G, Sliskovic M. The Impact of Fish Cages on Water Quality in One Fish Farm in Croatia. In: Proceedings of the International Conference on Biological, Biomolecular and Biomedical Sciences (ICBBBS 2010); c2010 Aug 25-27; Paris, France. World Academy of Science, Engineering and Technology; c2010. p. 868-871.
21. FAO. The State of World Fisheries and Aquaculture 2024. Blue Transformation in action. Rome: FAO; c2024. DOI: 10.4060/cd0683en.
22. Degefu F, Mengistu S, Schagerl M. Influence of fish cage farming on water quality and plankton in fish ponds: A case study in the Rift Valley and North Shoa reservoirs,

Ethiopia. Aquaculture. 2011 Jun;316(1-4):129-135.
23. Komakech R, Kang Y. Ethnopharmacological potential of African cherry [*Prunus africana*]. J Herb Med. 2019 May-Jun;17:100283.
24. Baluku E, Tumwebaze A, Twinomujuni D, Sabino FO, Komakech R. Caught In The Plastic Trap: Understanding the Obstacles to Combating Plastic Pollution In Uganda. A Review. International Journal of Engineering Applied Sciences and Technology. 2024;9(2):1-7.
25. Azizpour J, Manbohi A, Rahnama R, Hamzepour A, Bastami KD, Bagheri H, *et al*. Environmental impacts of fish cage cultures in the southern Caspian Sea. Environ Res. 2025 Feb;266:120574.
26. Kalantzi I, Black KD, Pergantis SA, Shimmield TM, Papageorgiou N, Sevastou K, *et al*. Metals and other elements in tissues of wild fish from fish farms and comparison with farmed species in sites with oxic and anoxic sediments. Food Chem. 2013 Nov 1;141(2):680-694.