



Strengthening aquaculture governance in Lake Victoria: A precautionary case for controlled fish seed production

Yona G.K.^{1*}; Ndawala M.A.²

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Abstract

Lake Victoria is a transboundary ecosystem shared by Kenya, Uganda, and Tanzania that supports capture fisheries, aquaculture, food security, transport, domestic water use, and biodiversity. Cage aquaculture is expanding in the basin, but its environmental effects vary with site conditions, hydrodynamics, stocking biomass, feed inputs, farm management, and background water quality. This policy-oriented opinion paper argues that commercial fish seed production and early nursery operations represent a distinct regulatory control point for biosecurity, genetic containment, traceability, and auditability. Although Kenya, Uganda, and Tanzania have regulatory frameworks addressing aquaculture, fish seed, environmental assessment, confinement, and hatchery operations, and regional LVFO/EAC instruments provide guidance on cage farming, fish seed certification, aquatic animal health, and natural nursery areas, an explicit and harmonized regional rule governing commercial hatchery and nursery activities in the open waters of Lake Victoria remains limited. The paper proposes a precautionary regional approach under which commercial artificial breeding, egg incubation, broodstock conditioning for seed production, fry nursing, and fry-to-fingerling multiplication are conducted outside the open waters of Lake Victoria. Narrowly defined and time-bound research or conservation activities could be considered following rigorous risk assessment. Controlled facilities equipped with screened water intakes and outlets, effluent and sludge management, appropriate biosecurity measures, health certification, genetic provenance records, traceability systems, and live-fish movement permits should provide seed to authorized grow-out operations. This approach could strengthen responsible aquaculture governance while supporting ecosystem protection, biosecurity, and sustainable fish production in the Lake Victoria basin.

Keywords: Lake Victoria,, Cage aquaculture, Fish seed, Biosecurity, Aquaculture governance, Traceability

1-TAFIRI Dar es Salaam Centre, P.O. Box 78850, Dar es Salaam, Tanzania;

2-TAFIRI Kyela Centre, P.O. Box 98, Kyela, Mbeya, Tanzania

*Corresponding author's Email: gloria.yona@tafiri.go.tz

Introduction

Lake Victoria is one ecological system shared by three countries. Aquaculture decisions made in one national sector can create transboundary consequences through water movement, live fish transfers, disease transmission, escapes and cumulative nutrient loading (Njiru *et al.*, 2019). Regulation must therefore operate at farm, national and regional levels, consistent with the regional mandate of the Lake Victoria Fisheries Organization (LVFO) and the precautionary and ecosystem approaches promoted by FAO (FAO, 2011; FAO, 2025; LVFO, 2024).

The central opinion of this paper is that commercial artificial breeding, egg incubation, broodstock conditioning for seed production, fry nursing, fry-to-fingerling production and seed multiplication should not be routinely authorized in the open waters of Lake Victoria. Authorized grow-out cage farming may continue in approved zones, subject to carrying-capacity limits, environmental and social assessments, certified seed, feed, and biomass controls, fish-health requirements, escape-prevention measures, and enforceable water-quality monitoring.

This is a precautionary policy recommendation, not a finding that all nursery cages have been scientifically proven to cause greater nutrient pollution than grow-out cages. Nutrient and oxygen effects are driven chiefly by feed load, standing biomass, waste management, water exchange, depth, currents, and background trophic

condition. Recent Lake Victoria studies show both measurable cage-related differences in water quality and strong site-to-site variation, supporting site-specific limits and continuous monitoring rather than generalized assumptions (Musinguzi *et al.*, 2019; Mabula *et al.*, 2023; Okechi *et al.*, 2025). The stronger case for locating seed production in controlled facilities rests on containment, health surveillance, genetic governance, traceability, and the ability to isolate and disinfect a production unit.

Analytical approach

This paper is presented as a policy-oriented opinion and precautionary governance analysis. The argument is based on a targeted review of scientific literature on cage aquaculture, water quality, fish health, biosecurity, fish seed systems and genetic risks in Lake Victoria and comparable aquaculture systems, together with a review of national aquaculture legislation and regional LVFO/EAC instruments relevant to cage farming, fish seed certification, natural breeding and nursery areas, and aquatic organism health. The analysis focuses on whether commercial seed production and early nursery operations should be treated as a distinct regulatory category from grow-out cage farming in Lake Victoria's open waters.

Why open-lake seed and early nursery operations require a distinct rule

Open-water aquaculture directly exchanges water with the surrounding

lake. Feed residues, faeces, mortalities, biofouling materials and any improperly used treatments can enter the environment, while cultured fish and pathogens can move across the farm boundary. These risks also occur in grow-out systems and should not be attributed solely to the nursery stage. However, seed and early nursery operations add several management concerns that make them a distinct regulatory category.

First, early nursery cages commonly use small-mesh netting to retain fingerlings. Small mesh is more susceptible to biofouling and clogging, which can restrict water exchange and increase fish stress if nets are not inspected, cleaned, or progressively changed as fish grow. A 2026 survey of 172 cage operations in the Kenyan part of Lake Victoria found major biosecurity gaps, limited water-quality testing, and infrequent net cleaning or replacement; it also confirmed that small mesh can clog and restrict circulation (Teplitz *et al.*, 2026). The appropriate conclusion is not that nursery cages always pollute more, but that they require management intensity and oversight that are difficult to guarantee in dispersed open-water operations.

Second, the fish-seed chain represents a critical biosecurity control point because it links multiple stages of aquaculture production, including broodstock collection, spawning, larval production, grading, transport, and stocking. These interconnected pathways can facilitate the movement and amplification of pathogens between

hatcheries, nurseries, and grow-out farms, particularly when fish are transferred before infections become clinically apparent. Effective biosecurity in controlled production systems relies on measures such as quarantine, cohort separation, health screening, diagnostic testing, disinfection, fallowing, and traceable movement records (WOAH, 2024). However, open-lake cage systems cannot be completely isolated from the surrounding aquatic environment, requiring stronger preventive measures, early detection, and ecosystem-based risk management approaches (FAO, 2011). The regional aquatic organism health strategy for Lake Victoria accordingly emphasizes harmonized surveillance, movement controls, certification, and risk-based biosecurity among riparian states (LVFO, 2024).

Third, seed production raises genetic governance concerns. Escaped cultured fish may reproduce with wild stocks where they are fertile. The relevant risk is not simply that a fish is farmed, but whether the seed is non-native, hybrid, selectively bred, genetically divergent, inadequately documented, or unintentionally mixed sex. A regional rule should therefore require approved species and strains, verified broodstock origin, genetic provenance records, and escape-prevention plans, rather than treating all monosex or hatchery seed as equivalent risks (LVFO, 2022, 2024).

Fourth, operators may prefer sheltered, shallow and nearshore waters because they are accessible and easier to supervise. These areas can overlap with

natural fish breeding and nursery habitats, wetlands, drinking water intakes, navigation routes and small-scale fishing grounds. LVFO guidance already calls for identification, demarcation and protection of natural breeding and nursery areas, and studies in Lake Victoria show that careful site selection is essential (Aura *et al.*, 2019; LVFO, 2019; Mabula *et al.*, 2023). Aquaculture 'nursery cages' must not be confused with natural nursery habitats; the latter are ecological areas that should be protected from incompatible uses.

Fifth, open-lake seed operations are difficult to audit. Cages can be moved, batches can be split or combined, and seed can be sold or transferred rapidly. This complicates verification of broodstock origin, production volumes, health status, mortality, strain identity and movement history. Licensed controlled facilities are not risk-free, but screening of water inlets and outlets, effluent and sludge treatment, facility-level biosecurity, record keeping and inspection make the risks more containable and auditable.

Regulatory landscape and the actual gap

The three countries now have stronger aquaculture frameworks. Kenya's Fisheries Management and Development Act, 2016 expressly addresses transboundary aquaculture risks, and the Fisheries Management and Development (Aquaculture) Regulations, 2024 cover broodstock, hatcheries, fish seed, aquaculture development zones, environmental

assessment, escape control, traceability, biosecurity and hatchery infrastructure, including screened water inlets and outlets. Uganda's Fisheries and Aquaculture Act, 2023 requires confinement to prevent escape, environmental and social impact assessment for commercial aquaculture, sanitary and environmental safeguards, and certification for fish-seed production. Tanzania's Fisheries (Aquaculture) Regulations, 2024 regulate permits for hatcheries, cages, ponds, tanks and raceways for seed or grow-out, and Tanzania is actively expanding zoned cage aquaculture rather than maintaining a general historical restriction on cages (Government of Kenya, 2016, 2024; Government of Uganda, 2023; Government of Tanzania, 2024; FAO, 2026).

At the regional level, LVFO/EAC instruments address cage-farm siting and operation, natural fish breeding and nursery areas, fish seed and feed certification, and aquatic organism health. The relevant instruments include the 2018 cage-farming guidelines, the harmonized guidance on natural breeding and nursery areas, the 2022 regional fish-seed and fish-feed certification guidelines, and the Lake Victoria Basin Regional Aquatic Organisms' Health Strategy 2024–2034 (LVFO, 2018, 2019, 2022, 2024).

The regulatory gap is therefore not a complete absence of aquaculture law in Kenya, Uganda or Tanzania. Each country has legal instruments that regulate aquaculture licensing, fish seed, hatcheries, environmental safeguards,

biosecurity, confinement or escape prevention, and related production systems. In addition, LVFO/EAC instruments provide regional guidance on cage farming, fish seed and fish feed certification, aquatic organism health and protection of natural breeding and nursery areas. The remaining gap is more specific: there is still no explicit,

harmonized and enforceable Lake Victoria rule that treats commercial seed production and early nursery operations as a distinct location-sensitive activity that should normally be conducted in certified controlled facilities rather than in open public lake waters (Table 1).

Table 1: Regulatory coverage and remaining gap for Lake Victoria fish seed and nursery operations

Jurisdiction/institution	Relevant instrument(s)	What it already covers	Remaining gap relevant to this opinion paper
Kenya	Fisheries Management and Development Act, 2016; Fisheries Management and Development (Aquaculture) Regulations, 2024	Kenya's framework regulates aquaculture licensing, commercial aquaculture in public waters, development zones, hatcheries, fish seed production, broodstock, biosecurity, traceability, environmental safeguards, escape prevention, and fish-health-related controls.	There is still no explicit Lake Victoria-specific regional rule that prohibits or relocates commercial artificial breeding, fry nursing, seed multiplication, and early nursery operations from open public lake waters to controlled facilities.
Uganda	Fisheries and Aquaculture Act, 2023; related aquaculture rules/policy instruments	Uganda's Act requires licensing and permits for fisheries and aquaculture activities, includes provisions for fish seed production certification, and prohibits production, distribution, or sale of fish seed without a fish seed production certificate issued by the competent authority. It also provides for aquaculture management, confinement, environmental safeguards, and regulation of fish-seed systems.	Regulates fish seed and aquaculture activities, but the framework does not yet establish a harmonized Lake Victoria open-water location rule that clearly separates commercial seed/nursery operations from authorized grow-out cage farming.
Tanzania	Fisheries Act, 2003; Fisheries (Aquaculture) Regulations, 2024, Government Notice No. 885 of 2024; related water, land, environment, animal feed and animal disease legislation	Tanzania's aquaculture sector is regulated under the Fisheries Act of 2003 and the Fisheries (Aquaculture) Regulations of 2024. The framework covers aquaculture permits and regulated production systems, including hatcheries, cages, ponds, tanks, raceways, fish seed	There is no explicit shared Lake Victoria rule requiring commercial seed production and early nursery stages to be located in controlled facilities rather than open public lake waters.

Jurisdiction/institution	Relevant instrument(s)	What it already covers	Remaining gap relevant to this opinion paper
		and grow-out activities. The 2024 regulations also require good-quality seed from approved sources, water-quality monitoring, and measures to prevent entry of wild fish and escape of cultured organisms through secured inlets, outlets and overflows.	
LVFO / EAC	Guidelines for Establishment and Operation of Cage Fish Farming in the East African Community; Regional Guidelines for the Certification of Fish Seed and Fish Feed in the EAC, 2022; Lake Victoria Basin Regional Aquatic Organisms' Health Strategy 2024–2034; other LVFO/EAC regional guidance	LVFO/EAC instruments provide regional guidance on cage fish farming, cage siting, fish seed and fish feed certification, aquatic organism health, biosecurity, disease surveillance, natural breeding and nursery areas, and species-specific licensing for Lake Victoria.	Regional instruments provide a strong foundation, but the guidance has not yet been converted into a binding, harmonized, enforceable Lake Victoria rule that explicitly keeps commercial hatchery, fry nursing, fry-to-fingerling multiplication and early nursery operations out of open lake waters, while allowing certified seed from controlled facilities to supply authorized grow-out cages.

Conceptual model

Seed operations in open waters act as lake-wide sources of risk through frequent handling, batch mixing, disease amplification, escape, and genetic

introgression that are difficult to contain.

The preferred pathway uses certified land-based facilities enabling inspection, containment, and certification (Table 2).

Table 2: Conceptual pathway showing why commercial fish seed production and early nursery operations require stricter location control than grow-out cage farming in Lake Victoria.

A. OPEN-WATER HATCHERY / NURSERY – RISK AMPLIFICATION	B. PREFERRED PATHWAY – CERTIFIED CONTROLLED FACILITY
Broodstock / Hatchery / Fry / Nursery Operations in Open Waters	Certified Controlled Facility (Land-based / Biosecure)
Frequent Handling and Movement	Screened Intakes / Outlets and Physical Barriers
Batch Mixing and Traceability Risk	Quarantine and Diagnostics
Disease Transmission Risk	Effluent / Sludge Management
Escape and Genetic Introgression Risk	Genetic Provenance Records
Difficulty of Inspection and Containment	Movement Permits & Regulatory Oversight
Transboundary Lake-Wide Governance Risk	Certified Seed Supplied to Authorized Grow-out Cages

Sources: FAO (2025) Guidelines for Sustainable Aquaculture; LVFO (2018) Regional Guidelines for Cage Farming in Lake Victoria.

Proposed regional rule

Kenya, Uganda and Tanzania should adopt a harmonized LVFO/EAC precautionary standard and domesticate it through the appropriate national legal instruments, permit conditions and aquaculture development plans. The rule should use precise definitions and apply to commercial seed-production activity in Lake Victoria's open waters and in any connected public waters expressly designated by national law as part of the Lake Victoria aquaculture management area.

Proposed core provision: No person shall undertake commercial artificial breeding, spawning, egg incubation, larval rearing, fry nursing, fry-to-fingerling rearing, seed multiplication, or broodstock conditioning for seed production in the open waters of Lake Victoria. All fish seed intended for stocking in authorized Lake Victoria grow-out cages shall originate from a licensed and certified controlled facility with screened water intakes and outlets, effective effluent and sludge management, approved broodstock and genetic provenance, biosecurity and quarantine procedures, fish-health surveillance and certification, batch traceability, mortality records and valid live-fish movement documentation. A competent national authority may authorize time-bound research, diagnostic, or conservation trials only after a documented environmental, animal-health and genetic risk assessment, consultation with the relevant environmental authority, notification to the LVFO, strict

containment conditions, and public reporting of results.

The rule should preserve responsible grow-out aquaculture. Grow-out cages should be authorized only in approved zones after hydrodynamic and carrying-capacity assessments (FAO, 2010), environmental and social reviews, stakeholder consultations and confirmation that the site does not conflict with gazette natural breeding or nursery habitats, wetlands, water intakes, navigation routes, protected areas or priority fishing grounds. Permits should set enforceable limits for cage volume, stocking biomass, feed input, farm spacing, fallowing, mortalities, escapes and monitoring.

Implementation measures

Implementation should be coordinated through national fisheries authorities, environmental agencies, research institutions, local governments, Beach Management Units and LVFO. It should include the following measures:

- i. Immediate suspension of new commercial permits for open-lake hatchery, broodstock-spawning, egg-incubation, fry-nursing and seed-multiplication operations while the harmonized rule is finalized.
- ii. A basin-wide inventory, completed within six months of any existing open-water seed or early nursery operations, including location, operator, legal status, species, strain, source, cage dimensions, biomass, production volumes and movement pathways.

- iii. A risk-based transition plan, normally 12–24 months, for relocating lawful existing commercial seed operations to licensed controlled facilities. Shorter deadlines should apply where operations occupy protected habitats, lack permits, present immediate disease or escape risks, or obstruct other water users.
- iv. Certification and periodic audit of every hatchery and nursery supplying Lake Victoria farms, covering broodstock source, approved species and strains, genetic provenance, health surveillance, quarantine, screened intakes and outlets, effluent and sludge management, mortality disposal, batch records and live-fish movement permits.
- v. Aquaculture zoning should exclude gazette natural breeding and nursery areas, wetlands, shallow or poorly flushed eutrophic sites, drinking-water intakes, navigation routes, protected areas and other locations shown by environmental and social assessment to be unsuitable.
- vi. Zone- and farm-specific environmental monitoring is linked to baseline conditions and enforceable action thresholds. Core variables should include dissolved oxygen and temperature profiles, pH, transparency or turbidity, ammonia, total nitrogen, total phosphorus, chlorophyll-a, sediment organic enrichment, feed input, biomass, mortalities and hydrodynamic conditions, with monitoring frequency proportionate to farm scale and risk.
- vii. A shared regional information system and public compliance register showing farm location, legal operator, permit status, approved capacity, species and seed source, monitoring compliance and enforcement status. Personal data, commercially sensitive information and detailed disease investigations should be protected or reported in appropriately aggregated form.
- viii. Mandatory farm biosecurity plans, rapid disease and mass-mortality notification, standardized sampling and diagnostic protocols, safe mortality disposal, disinfection of shared equipment, cohort separation where feasible, and coordinated outbreak response under the LVFO regional health strategy.
- ix. Financial and technical support for compliant land-based or otherwise isolated hatchery and nursery infrastructure, including affordable diagnostics, certification, renewable-energy options, water treatment, extension services and transition assistance for small and community enterprises.

These measures build on, rather than replace, the existing legal frameworks of Kenya, Uganda and Tanzania and the current LVFO/EAC instruments. Their purpose is to establish a common minimum rule, improve implementation and close the cross-border enforcement gap.

Why the proposal is practical and proportionate

The proposal does not stop cage aquaculture or fish-seed investment. It reallocates commercial seed production to facilities where broodstock, cohorts, health status, genetic origin, effluent, escapes and sales can be inspected and documented. It also creates demand for certified hatcheries, aquatic animal health services, laboratories, water treatment systems, and professional extension services, thereby supporting a more reliable aquaculture value chain.

The recommendation is proportionate because it targets a defined activity and allows carefully controlled research or conservation exceptions. It also recognizes that controlled facilities must themselves be regulated: a poorly managed pond, flow-through hatchery or recirculating system can discharge pathogens or nutrients if outlets, sludge and mortality are not properly managed. Location alone is not sufficient; containment and operating standards are essential.

Lake Victoria is a shared public ecosystem, not a private production pond. Where a production stage can be conducted effectively in a controlled setting, while the same stage in open water creates harder-to-audit transboundary risks, precaution supports assigning that stage to the controlled setting. Governments should pair the restriction with transparent transition rules, affordable compliance pathways and support for affected small-scale operators.

Conclusion

Lake Victoria needs both responsible aquaculture development and stronger protection of water quality, natural breeding habitats, wild genetic resources, and aquatic animal health. The evidence does not justify claiming that every nursery cage is inherently more nutrient-polluting than every grow-out cage. It does justify treating commercial seed production and early nursery operations as a distinct biosecurity, genetic-containment and traceability control point that should, as a regional default, be kept out of open lake waters.

A harmonized LVFO/EAC rule, implemented through the existing laws of Kenya, Uganda and Tanzania, would clarify this boundary while allowing regulated grow-out in suitable zones. Certified controlled seed systems, transparent movement records, environmental thresholds, disease surveillance, genetic safeguards, and joint monitoring would strengthen, rather than undermine, the Lake Victoria aquaculture industry. Responsible fish production and ecosystem protection can advance together when regulation is evidence-based, precise and enforceable.

Ethics approval

The study did not require approval by an ethics committee.

Data availability

No new field data were generated or analyzed in this paper. The analysis is based on published literature, national legal instruments, and regional LVFO/EAC guidance cited in the manuscript.

Declaration of the use of AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used AI and AI-assisted tools to support language editing and proofreading. After using this tool, the author reviewed and edited the content, including references, interpretation, and conclusions, and takes full responsibility for the content of the publication. All content reflects the author's original work.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions

Gloria Kavia Yona: Conceptualization, policy analysis, writing – original draft, writing – review and editing. Msafiri Andrew Ndawala: Technical review, Writing – review and editing.

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