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WORLD AGRICULTURE FORUM

Blue Economy Rising

Oceans, Aquaculture, and the Future of Food Security

GLOBAL POLICY REPORT

PRESENTED BY

World Agriculture Forum

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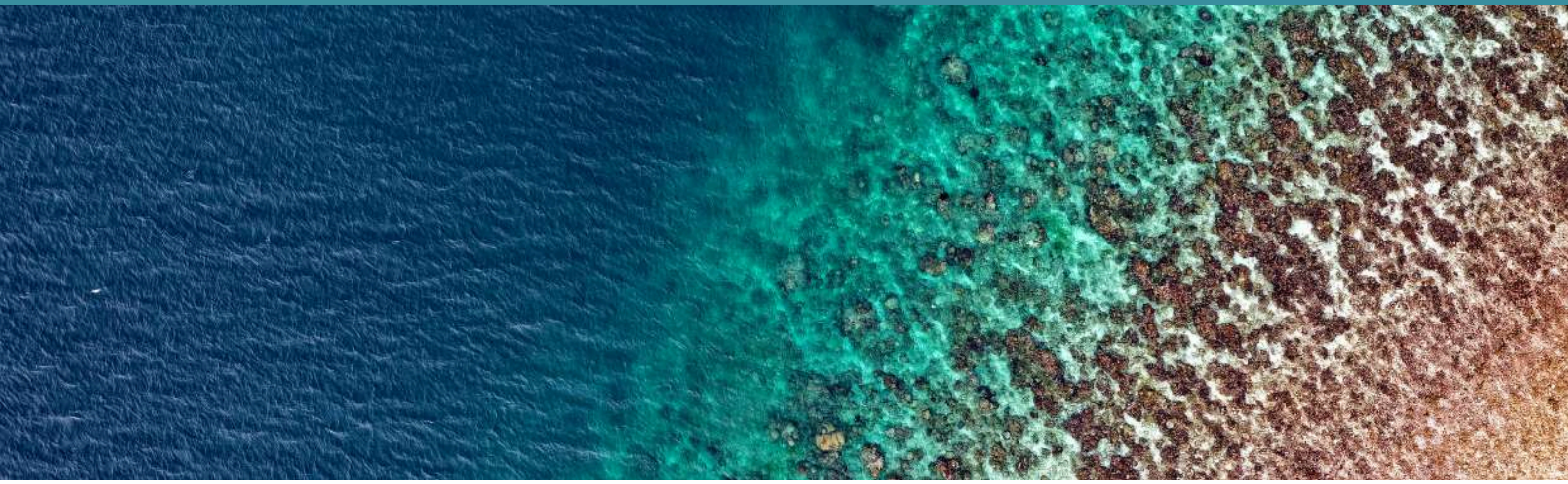
About This Report



Purpose and Scope

Blue Economy Rising: Ocean, Aquaculture, and the Future of Food examines the emerging opportunities and structural challenges shaping the future of aquatic food systems. The report focuses on the intersection of aquaculture, food security, environmental sustainability, technology, investment, infrastructure, governance, and inclusive economic development.

Its purpose is to identify the conditions required for aquatic food systems to move from incremental growth to sustainable transformation. It considers both the global picture and the specific constraints and opportunities facing emerging markets, with particular attention to the lessons emerging from India and the infrastructure, production, and market realities of sub-Saharan Africa.

Rather than treating aquaculture as a standalone production sector, the report considers it as part of a wider food and economic system. It therefore examines not only how more aquatic food can be produced, but how production can become more resource-efficient, commercially viable, environmentally responsible, and inclusive of small-scale producers and local communities.

The report is intended for policymakers, investors, development institutions, researchers, industry leaders, producer organisations, and civil society practitioners working across aquatic food systems and the Blue Economy.

Approach and Methodology

The report is a synthesis of the evidence, perspectives, and recommendations presented during the WAF High-Level Policy Dialogue on “Blue Economy Rising: Ocean, Aquaculture, and the Future of Food”.

The analysis brings together perspectives spanning international governance, national agricultural and fisheries research, production technology, investment and economic development, and frontline aquaculture production. Rather than reproducing individual presentations, the report organises these contributions around the central systemic questions emerging from them: What is constraining the next phase of aquatic food production? Which solutions are already proven? Why are they not reaching wider adoption? And what institutional, financial, technological, and infrastructural conditions are required to scale them?

The report follows a thematic rather than speaker-by-speaker structure. Evidence and perspectives have been synthesised across contributions to identify areas of convergence, illustrate contrasting regional realities, and draw out implications for policy and investment.

Evidence and Sources

The report distinguishes between evidence presented by participants and external reference material.

Where quantitative figures, production data, projections, or specific claims are attributed to the FAO, ICAR, Future Aquaculture, or other institutions, these are identified accordingly. The report also references authoritative external sources where they provide the appropriate factual or policy context, for example, FAO's The State of World Fisheries and Aquaculture 2026 and the Guidelines for Sustainable Aquaculture.

Figures and data originating directly from the policy dialogue are presented as stated by participants. Where the underlying information was incomplete, uncertain, or not sufficiently detailed to support a quantitative representation, the report does not infer or manufacture additional data.

This approach is intended to preserve the distinction between documented evidence, participant perspectives, and the report's synthesis and recommendations.

Limitations and Attribution

This report is a synthesis document, not a verbatim record or an institutional position paper. It reflects the evidence and perspectives considered in the policy dialogue and the analysis undertaken by the World Agriculture Forum Secretariat.

Participant views are not necessarily shared by the organisations with which they are affiliated. Recommendations in the report represent the synthesis of issues and priorities emerging from the evidence and discussion; they should not be interpreted as formal positions of FAO, ICAR, Future Aquaculture, or any other participating institution unless explicitly stated.

Where the report identifies areas requiring further evidence, validation, or investment, these should be understood as priorities for continued research and policy development rather than definitive conclusions.

A Note on the Charts

The charts in this report plot only values that speakers stated on the record. Where a chart would have required interpolation, projection, or invented intermediate data points in order to be visually complete, that chart has been omitted rather than constructed. Several topics discussed at length in the dialogue, including the regional distribution of production beyond Asia's share and the comparative infrastructure position of African producers, are therefore treated in prose rather than in charts.

Foreword

Ask someone what they picture when they hear "fish farm," and most will describe something small like a pond, a net, a family operation on a riverbank. Few will picture what the sector has actually become: a production system now larger than everything the world's oceans yield combined, quietly responsible for more of what ends up on dinner plates than the fishing fleets that used to define the industry entirely. It happened within a single working lifetime. Most people, including many who work adjacent to it, have not caught up to what it now is.

We wrote this report because we noticed a second thing people haven't caught up to: this remarkable growth story is running out of road, and not for the reasons anyone expects. It isn't running out of science. Every technical problem this sector faces such as closing the nutrient loop, farming within ecological limits, doing more with less land and water has already been solved, by someone, somewhere, at a profit. We visited some of those places. The solutions are not fragile or theoretical. They are sitting in commercial ponds and tanks right now, working.

What is missing is harder to put a number on: the willingness to move a working idea from where it was proven to where it is needed, even when that means crossing a border, a funding cycle, or an assumption about who gets to be an investable business. Across every domain we examined (production technology, national policy, investment, community infrastructure) the same pattern recurred, and it was never that a solution didn't transfer. It was that nothing had been built to carry it. Closing that gap is a harder, slower, and less glamorous task than inventing the next technology. It is also the one that will actually determine whether the next twenty years of aquaculture look like the last twenty, or better. And it is remembering, at every stage, that the person actually holding the net or tending the tank is not only a beneficiary of this transformation but they are the reason it is possible at all.

This report is our attempt to say plainly what we saw and what we think it means, without softening the parts that are uncomfortable. We hope it is read the way we intend it, not as a summary of a moment, but as an argument for what should happen next, and as an invitation to the people who can actually make it happen.

The World Agriculture Forum
Future Aquaculture

Executive Summary

Aquaculture has quietly become the world's most important food-production story. It now supplies more aquatic food than the oceans do; capture fisheries have been flat for two decades, so virtually every additional fish the world eats in the next twenty years will come from a farm, not a net. And yet the growth rate of that farming system is projected to fall by 60% over the coming decade, precisely when demand is set to keep climbing.

This is not a story about missing technology. Every constraint this report examines, be it ecological, financial or institutional has already been solved somewhere, at commercial scale, at a cost lower than the status quo. India took its aquaculture sector from under 1 million tonnes to nearly 20 million tonnes through seventy-five years of sustained public investment. Biofloc systems operating commercially in Ghana cut land use by a factor of twenty and water use by a factor of thirty while discharging nothing. A one percent diversion of existing irrigation water in South Africa's Western Cape, requiring no new land or water rights, could match the country's entire wild-caught hake quota. None of this is theoretical, and none of it is expensive to replicate in engineering terms.

What is expensive and is the actual binding constraint on the sector's next twenty years is the alignment problem. Proven solutions do not travel to places with comparable conditions. Capital sits available in unprecedented quantities but will not fund innovation that hasn't yet proven it can generate returns, and value creation is treated as something to pursue after financing rather than before it. Partnerships convene the right institutions in the same room without organising them around a shared, accountable outcome. And the actors most essential to the system's function like small-scale producers, coastal communities, women, emerging-market fishers are the ones most consistently excluded from the investment, governance, and value chains built around them.

That last point is not a separate equity concern sitting alongside the sector's technical and financial challenges. It is the same failure recurring in a different domain. The system had been designed around whoever held the most leverage, and the cost of that design was quietly absorbed by whoever held the least, smallholders locked out of export-grade value chains, distant farmland and forests absorbing the footprint of feed sourcing, upstream polluters never held accountable for contamination that aquaculture inherits downstream, national capability assumed to exist in exactly the countries that need help building it. A sector that keeps solving each of these as an isolated problem will keep being surprised by the same pattern showing up somewhere new.

The path forward is therefore not a longer list of pilots or another round of proof-of-concept funding. It is the deliberate construction of the architecture that connects what already works to where it is needed: national policy aligned to existing international guidelines rather than reinvented from scratch; research funding structured in decades rather than project cycles; energy and cold chain investment sequenced to unlock the infrastructure built on top of them; capital that follows demonstrated value rather than substituting for it; and territorial strategies that build each region's actual competitive advantage rather than importing someone else's. None of these require new invention. They require the sector to stop treating alignment as an afterthought to innovation, and start treating it as the primary design problem it is.

The window to do this is narrower than the sector's own optimism suggests. A growth curve that is already decelerating does not wait for governance to catch up.

> *I don't think this sector has a villain. Nobody sat down and decided to leave smallholders out, or to let a good technology sit unused for a decade. It happened because every actor optimized for what was in front of them, and nobody was responsible for the space between them. That space is where the next twenty years will actually be won or lost."*
>
> *— Dr Alix Willemez, Expert of World Ocean Assessment II & III, United Nations.*

Key Messages

1 **Aquaculture is now the dominant source of aquatic food, but growth is decelerating sharply.** Global aquatic food production reached a record 142 million tonnes in 2024, including 103 million tonnes of aquatic animals. Capture fisheries production has been stagnant for nearly two decades, so all future supply growth must come from aquaculture. Yet FAO projects the aquaculture growth rate will fall from 4.0 percent per year (2012 to 2022) to 1.6 percent per year (2022 to 2032), driven by water constraints, limited suitable sites, rising disease incidence, and stricter effluent regulation.

2 **The gap between what works and what is applied is systemic, not technical.** Proven technologies and governance models exist and operate at commercial scale. They are not being applied in contexts with comparable climate, resources, and demand. The barriers are governance capacity, investment alignment, institutional coordination, and the structural exclusion of small-scale actors, not a shortage of scientific knowledge.

3 **Circular production systems are commercially proven and deliver order-of-magnitude resource savings.** Biofloc technology recovers up to 80 percent of fed nitrogen in fish biomass; a full closed-loop system adding sea lettuce and salicornia reaches approximately 90 percent, achieving zero discharge. Compared with conventional ponds, biofloc production in Ghana has cut land footprint by a factor of 20 and water use by a factor of 30, with feed conversion of 1:1 on a 20 percent protein feed.

4 **Integrating aquaculture with agriculture is the largest immediately available opportunity.** Using source water for fish farming first and the nutrient-rich discharge for crop irrigation eliminates effluent, displaces chemical fertiliser, and returns organic carbon to soils. In the Western Cape of South Africa, diverting just 1 percent of irrigation water through biofloc tilapia culture would produce a volume equivalent to the entire national Cape Hake quota of 100,000 to 140,000 tonnes per year.

5 **Investment follows value creation. It cannot substitute for it.** The assumption that access to finance is the binding constraint on blue economy scale-up is mistaken. Unprecedented capital is available. Capital does not flow because an idea is innovative or well intentioned; it flows to businesses that can demonstrate the capability to compete and generate sustainable returns. Building productive economic systems must precede seeking finance, not follow it.

6 **National transformation requires sustained, convergent public investment over decades.** India's rise from eighth to second largest producer, from under 1 million tonnes to approximately 19.75 million tonnes, rested on research institutes established in 1947 and expanded over 75 years, 35 years of continuous selective breeding, a 15-year national disease surveillance programme, and deliberate laboratory-to-land technology transfer. Private investment cannot substitute for this foundation.

7 **In sub-Saharan Africa, energy cost is the primary structural barrier to smallholder participation.** Input costs in Ghana run two to six times higher than in comparable markets, with electricity the dominant driver. Reward-based financing for solar energy can reduce power costs to approximately one quarter of current levels, which in turn makes cold chain investment viable and brings smallholder production costs within competitive range.

8 **Territorial blue clusters, not replicated global models, are the scalable unit of transformation.** Each territory has its own combination of resources, scientific capability, and market position. The task is not to replicate a single model everywhere but to help each territory organise its capabilities around the specific competitive opportunity it actually has. Organised local competitive strength is what produces durable industries rather than temporary projects.

1. The Global State of Aquatic Food Systems

Aquatic food systems are becoming increasingly central to global efforts to achieve food security, improve nutrition, create sustainable livelihoods, and build climate resilience. As terrestrial agriculture faces mounting pressures from land degradation, water scarcity, biodiversity loss, and a changing climate, oceans, inland waters, and aquaculture are expected to play a growing role in meeting future food demand. Yet this opportunity comes at a time when aquatic food systems themselves are confronting ecological limits, uneven regional development, and the need for new production models that balance economic growth with environmental sustainability.

Recent evidence presented in the FAO's The State of World Fisheries and Aquaculture 2026 (SOFIA 2026)[1] highlights both the remarkable progress achieved and the structural challenges that lie ahead. Global production has reached record levels, driven largely by the rapid expansion of aquaculture, which has become the principal source of aquatic animals for human consumption. At the same time, slowing production growth, increasing environmental pressures, resource constraints, and widening regional disparities underscore the need for a new phase of development focused on productivity, sustainability, and resilience.

The following sections examine the current state of global aquatic food systems through four interrelated dimensions: production trends, employment and livelihoods, emerging growth constraints, and the uneven geographical distribution of aquaculture development. Together, they illustrate why strengthening aquatic food systems has become both a food security imperative and a central pillar of the global Blue Economy.

1.1 A Sector at a Historic Turning Point

Global aquatic food production reached a record 142 million tonnes, of which 103 million tonnes were aquatic animals.[2] Aquaculture, which began as a modern sector only in the 1950s, has grown at an average of 4.9 percent per year since 2000 and is now the principal source of aquatic animals for human consumption. By contrast, capture fisheries production has been stagnant for close to two decades, meaning that virtually all future growth in aquatic food supply will need to come from aquaculture.

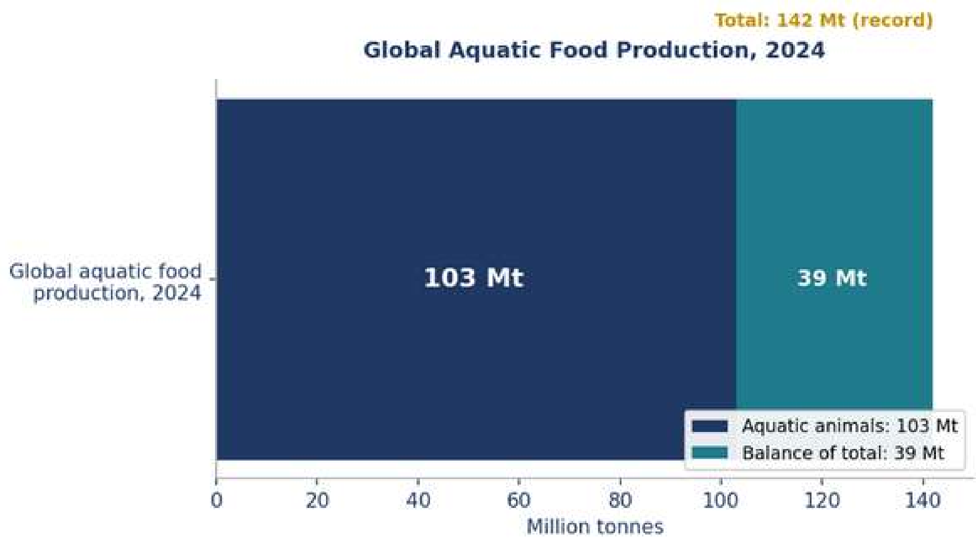


Figure 1. Global aquatic food production, 2024. Source: FAO State of World Fisheries and Aquaculture 2026, as presented in the dialogue.

[1] [2]*FAO, The State of World Fisheries and Aquaculture 2026: Blue Transformation in Action (Rome: Food and Agriculture Organization of the United Nations, 2026).*

The conceptual distinction between the two production modes matters. Capture fisheries is hunting: extracting fish from the ocean or from other water bodies. Aquaculture is farming: providing inputs and producing what is wanted. This makes aquaculture business-driven and consumer-driven in a way capture fisheries is not, because the species cultured are the species consumers demand.

1.2 Employment and Livelihoods

Approximately 60 million people are directly employed in fisheries and aquaculture. Approximately 600 million livelihoods depend on fisheries and aquaculture value chains. The sector therefore contributes not only to food security and nutrition but to economic development, particularly in coastal communities and in less developed regions.

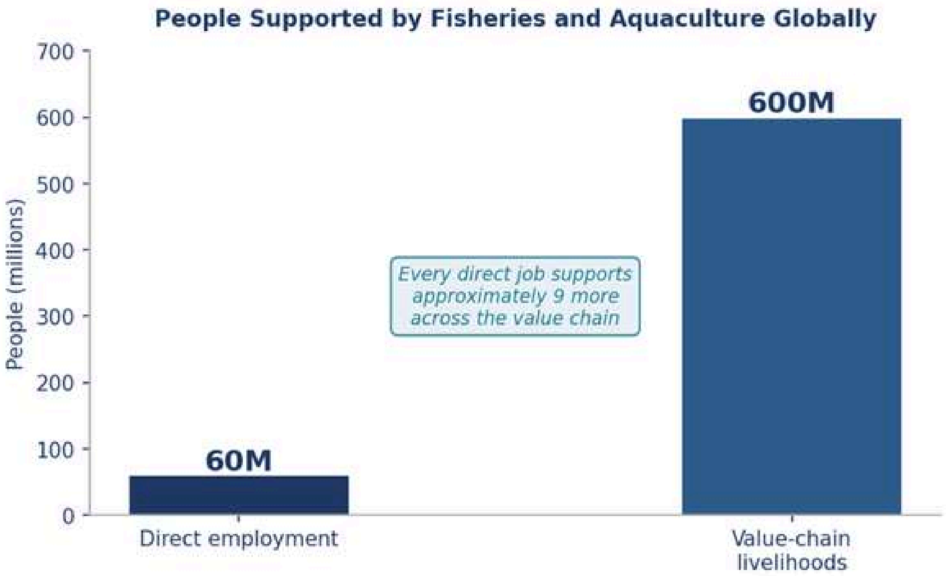


Figure 2. People supported by fisheries and aquaculture globally. Source: FAO figures presented in the dialogue.

1.3 The Deceleration Challenge

Despite these achievements, aquaculture growth is slowing sharply. FAO projects the sector's growth will fall from 4 percent per year over 2012 to 2022, to 1.6 percent per year over 2022 to 2032. Four drivers of this deceleration were identified: water quality and quantity constraints; limited availability of suitable sites; increased incidence of aquatic animal diseases; and stricter regulation of effluent discharge permitting.

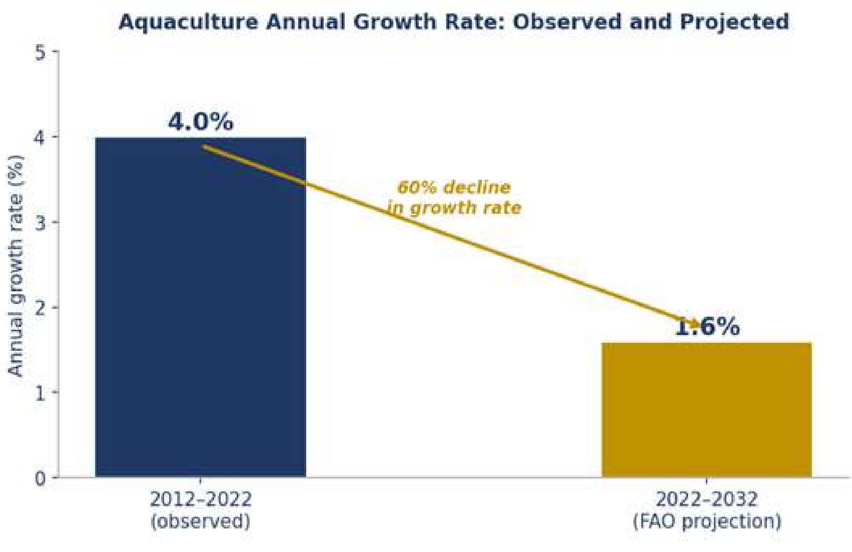


Figure 3. Aquaculture annual growth rate, observed and projected. Source: FAO projections presented in the dialogue

The significance of this deceleration is that demand is not decelerating with it. The gap between a slowing supply system and continuing demand growth is the central production problem the dialogue set out to address. It cannot be closed by doing more of what the sector already does; it requires a change in how production works.

1.4 A Profoundly Unequal Global Distribution

Production is concentrated in Asia to a degree without parallel in any other major food sector. Asia produces approximately 90 percent of the world's farmed aquatic animals. Africa and the Caribbean, by contrast, remain predominantly dependent on capture fisheries.

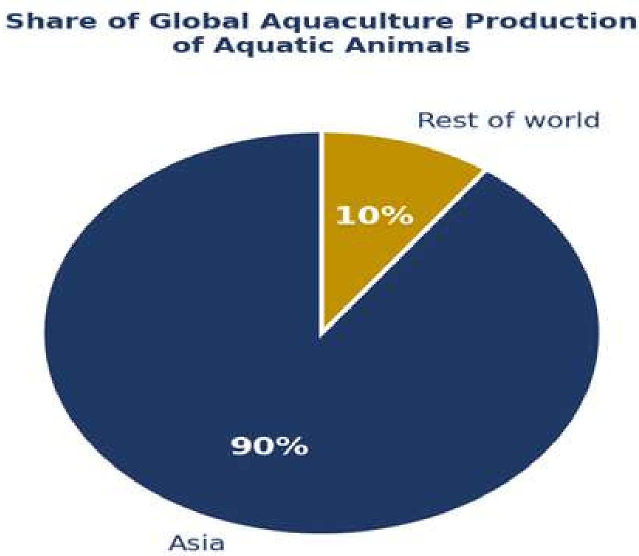


Figure 4. Asia's share of global aquaculture production of aquatic animals. Source: FAO figures presented in the dialogue. The dialogue did not provide a breakdown of the remaining share by region, and none is presented here.

Asia's dominance was attributed to its long history and cultural tradition of aquatic food production and consumption. FAO's outlook targets an increase in African aquaculture production of approximately 75 percent in the coming years. Reaching that target, in FAO's assessment, will require the transfer of technology and enterprise from Asia and elsewhere into African markets, alongside enabling governance and infrastructure that does not yet exist at scale.

2. The Systemic Gap: Why Knowledge Does Not Become Practice

2.1 The Gap Is Not Technical

The barriers to sustainable and equitable aquaculture growth are not primarily technical. Proven technologies exist and operate at commercial scale. India has demonstrated that sustained science-based development can drive national production from under 1 million tonnes to nearly 20 million tonnes. Biofloc systems in Ghana have cut land use by a factor of 20 and water use by a factor of 30 while eliminating effluent discharge. Integrated multi-trophic systems recover close to 90 percent of fed nitrogen. None of this is theoretical: these are operating systems generating revenue today, not pilot projects awaiting validation.

That distinction matters because it reframes what kind of problem the sector is actually facing. If the constraint were technical, the solution would be more research, more time, more engineering. It is not. The gap is systemic, spanning governance and capacity, investment alignment, institutional coordination, and the inclusion of small-scale actors. Technologies and innovations already proven in India or elsewhere are not adopted in other regions, even where the climate, natural resources, and consumer demand are comparable. A biofloc system that eliminates effluent discharge in Ghana is not, in principle, harder to replicate, the biology and engineering transfer readily. What does not transfer automatically is the surrounding architecture: the extension services that get a technology into a farmer's hands, the finance structured for the risk profile of an unproven-locally system, and the institutional relationships that make national-scale rollout possible.

This is evidence of a shortfall in knowledge sharing and in the investment needed to replicate proven models in new contexts, not a shortage of working solutions. The practical implication is that closing the gap is less an R&D problem than a diffusion problem and diffusion problems are solved by different actors, on different timelines, using different instruments (extension networks, blended finance, regional knowledge platforms) than technical ones.

2.2 The Design-for-Adoption Problem

A second dimension of the transfer failure concerns how technologies are designed in the first place. Research is typically produced within projects of three to five years, funded and structured around publication or pilot-completion milestones rather than field-scale rollout. When a project closes, the knowledge often does not travel with it; it sits in a report or a research station rather than moving into the hands of the next farmer who could use it.

But there is a deeper issue beneath the funding-cycle problem: the technologies that spread furthest are those designed for ease of adoption, not those that are most technically sophisticated. Most farmers, in most countries, including in India where the sector is highly developed, do not have the technical knowledge base to adopt complex systems without sustained support. A system that requires continuous water-chemistry monitoring, specialized inputs, or trained technical staff to operate correctly will work well wherever that support exists and nowhere else. Technology requiring extensive technical management will therefore remain confined to a small number of sophisticated operators, however effective it is in controlled conditions.

The implication is that simplicity, affordability, and relevance to the conditions of the ultimate user must be design criteria from the outset, not considerations bolted on after a technology has already been developed and proven in a research setting. A system engineered first for performance and only later adapted for accessibility tends to lose much of its performance advantage in the adaptation retrofitted simplicity is a poor substitute for technology designed for low-resource operation from the start. Scalability, in other words, is not a downstream deployment question. It is determined at the design stage, before the first prototype is built.

2.3 The Four Dimensions That Must Align

Four dimensions must evolve in coordination rather than in parallel. Where they evolve separately, solutions that exist in one part of the system do not translate into systemwide change.

	Dimension	Constraint	Response
1	**Scientific knowledge and innovation**	Proven technologies are not transferred to comparable contexts; research remains project-bounded	Cross-country knowledge exchange; design for ease of adoption from the outset
2	**Production systems and industry practice**	Open-discharge pond systems remain dominant; nutrients are wasted and discharged	Circular systems: biofloc, integrated multi-trophic aquaculture, aquaculture-agriculture integration
3	**Production systems and industry practice**	Open-discharge pond systems remain dominant; nutrients are wasted and discharged	Circular systems: biofloc, integrated multi-trophic aquaculture, aquaculture-agriculture integration
4	**Infrastructure, markets and investment**	Energy and cold chain gaps exclude smallholders; capital seeks innovation rather than value creation	Reward-financed energy investment; cold chain; cooperative markets; value creation before finance

The real gap is not technical. It is systemic: governance and capacity, investment alignment, institutional coordination, and the inclusion of small-scale actors."
—Xinhua Yuan, Deputy Director, Fisheries and Aquaculture Division, FAO

3. Science, Innovation, and the Lessons from India

3.1 The Anatomy of a National Transformation

India's rise from eighth to second largest fish producer and second largest aquaculture producer is the most instructive national case study available, because it demonstrates that supply-side transformation at national scale is achievable within a single working lifetime. Production has grown from less than 1 million tonnes to approximately 19.75 million tonnes. The national vision for 2047 targets 40 million tonnes, of which approximately 32 million tonnes would come from aquaculture implying the aquaculture sector alone would need to roughly double again from current levels.

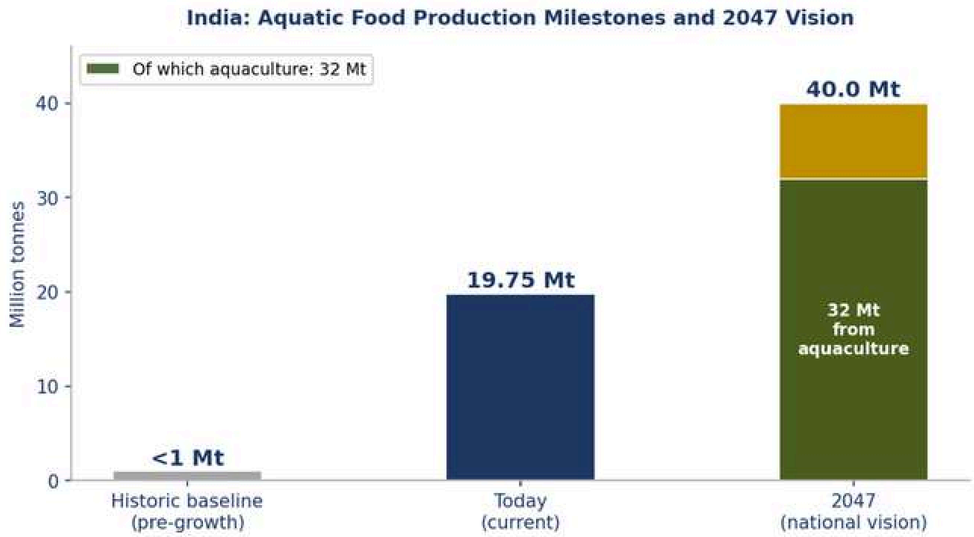


Figure 5. India's aquatic food production milestones and the 2047 national vision. Source: figures presented in the dialogue by the Deputy Director General for Fishery Science, ICAR.

What makes the trajectory instructive is not the growth rate alone but its foundation: the gains were not opportunistic, they were engineered. The foundations were laid before independence. Two national research institutes were established in 1947: the Central Marine Fisheries Research Institute and the Central Inland Fisheries Research Institute, at a moment when the newly independent state had little institutional capacity to spare. Forty years later the network was expanded to eight institutes, including two focused exclusively on aquaculture: the Central Institute of Freshwater Aquaculture, and a counterpart institute for brackishwater aquaculture. This institutional continuity reflects a sustained conviction that research investment in aquaculture returns value, maintained across seven decades and multiple political cycles; a degree of policy persistence that is itself a scarce resource in most developing aquaculture sectors.

The Drivers of India's Success

1. **Sustained and increasing public investment:** Budgets have risen consistently over decades. The government has since established a dedicated ministry and the National Fisheries Development Board, whose function is to connect research to the ultimate stakeholders, addressing the diffusion gap described in Section 2 directly, through institutional design rather than hope.
2. **Species diversification:** India has expanded from 68 farmed species to more than 80–90 species with available breeding and farming technology, with plans to add another 10, spreading production risk across species and reducing dependence on any single market.

3. **Long-run genetic improvement:** Selective breeding programmes for rohu, catla, freshwater prawn and other species have run continuously for 35 years, a timescale that reflects the slow compounding nature of genetic gain in aquaculture broodstock.
4. **Private sector mobilisation:** More than 3,000 carp hatcheries and more than 500 shrimp hatcheries now operate. India has moved from importing feed and health management methods to exporting them, marking the transition from technology recipient to technology exporter.

- **Disease surveillance:** A national surveillance programme has run consistently for 15 years, addressing one of the most significant near-term constraints on the sector globally: disease outbreaks that can wipe out a season's production with little warning.
- **Laboratory-to-land programmes:** Deliberate outreach connects research outputs to farmers. One freshwater cluster covering 100,000 hectares has operated for 30 years; proof that the design-for-adoption problem described in Section 2.2 is solvable at scale, given sustained institutional commitment.
- **New generation farmers:** Young, professional entrants bring risk-taking capacity and the ability to think at scale, a demographic shift that reinforces rather than replaces the institutional drivers above.

3.2 Export Reach and Untapped Potential

India exports approximately 8.3 billion US dollars of fish and fishery products annually. Shrimp alone accounts for approximately 5 billion of that total. Yet only about 15 percent of the potential production area is currently in use meaning the export figures above, substantial as they are, represent a fraction of what the resource base could ultimately support.

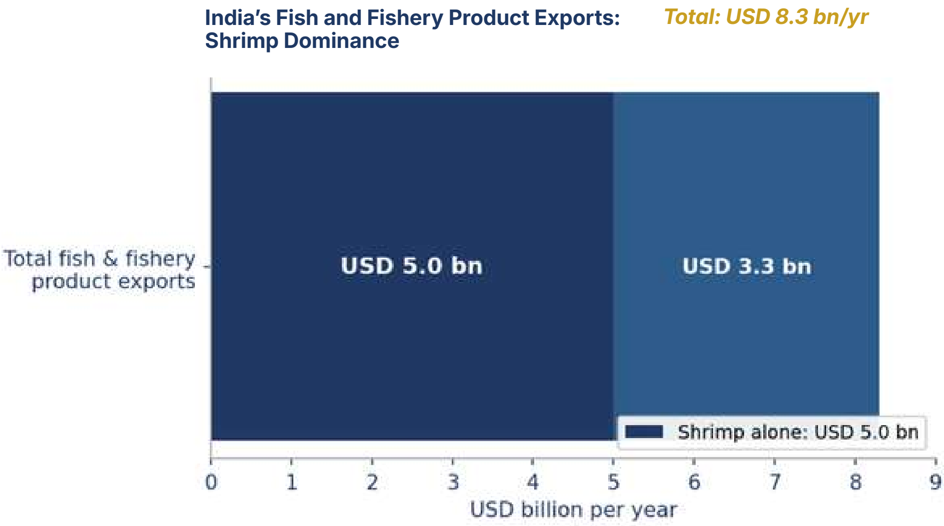


Figure 6. India's fish and fishery product exports and the dominance of shrimp. Source: figures presented in the dialogue.

The implication cuts two ways. On one hand, the production that has already made India the world's second largest producer has been achieved on a fraction of the available resource base, suggesting substantial further headroom without requiring new land or water allocation. On the other, it concentrates risk: a single commodity accounts for roughly 60 percent of export value, and 95 percent of shrimp production comes from small and marginal farmers holding ponds of one to five hectares. That combination, commodity concentration sitting on top of smallholder concentration means a shrimp-specific shock (disease, a trade barrier, a demand collapse in a key export market) would transmit directly to hundreds of thousands of small producers with little buffer, rather than being absorbed by a few large operators.

3.3 From Input-Based to Knowledge-Based Aquaculture

A fundamental transition will determine which producers succeed over the next twenty years. The model that has driven growth to date is input-based aquaculture, dependent on increasing quantities of feed, chemicals, and land. That model is reaching its limits: feed ingredients are finite and increasingly contested, land and water allocation face competing claims, and the ecological cost of input-intensive systems is no longer externalizable at the scale the next phase of growth requires.

The next phase is knowledge-based aquaculture, defined by the ability to harness genetic potential, manage disease through surveillance and biosecurity rather than reactive treatment, adapt to climate variability, and compete for feed ingredients such as fishmeal and soybean against the poultry and livestock sectors. This is a different competitive skill set than the one that built the sector to its current size, it rewards institutional depth and technical sophistication over raw input access, which is precisely why countries without India's research infrastructure risk being structurally disadvantaged in the next phase even if they were competitive in the last one.

The priorities that follow are the harnessing of the genetic potential of species through selective breeding, marker-assisted selection and genome editing; climate adaptation and mitigation strategies; disease management through surveillance; and resolution of intersectoral competition for feed ingredients. Alongside these, water quality and quantity, food safety, and traceability mark a decisive shift in the sector's goals. Thirty or forty years ago there was a single goal, which was increasing production. Today, quality and safety carry equal weight; a shift that changes what "success" means for a producer, and therefore what kind of support, financing, and regulation the sector needs going forward.

Input-based aquaculture was not a mistake, it was the right strategy for the stage we were at. But a strategy that depends on adding more feed, more land, more water to get more fish has a ceiling, and we are close enough to see it. What comes next has to come from what we know, not what we consume."
—Dr. Joykrushna Jena, Deputy Director General (Fisheries Science), ICAR – Indian Council of Agricultural Research

4. Technology and Production: Circular Systems as the New Standard

4.1 The Open-Loop Problem

Conventional pond aquaculture, still the dominant production model globally, operates on an open-loop principle. Inputs enter the system; a fraction is converted into fish biomass; the remainder is discharged as nutrient-rich effluent into surrounding waterways. This causes eutrophication and biodiversity damage, provokes regulatory restriction, and wastes the nutrients that were paid for in the feed, a system that is, in effect, paying twice for the same nitrogen: once to buy it as feed, and again in the ecological and regulatory cost of releasing it unused. The response is to close the loop: to redesign production so that nutrients are captured and reused within the system rather than treated as waste to be discharged.

4.2 Nitrogen Recovery in Circular Systems

In a biofloc system, bacterial communities in the water column absorb dissolved nitrogen and convert it into microbial floc, which filter-feeding fish such as tilapia consume directly. This biological cycling within the tank reduces feed cost, removes the need for water exchange, and largely eliminates effluent. Up to almost 80 percent of the nitrogen fed into a biofloc tilapia system is recovered in fish biomass, a striking figure against a conventional pond, where the majority of applied nitrogen is typically lost to sediment or discharge rather than converted into harvestable protein. Adding sea lettuce cultivation in the discharge stream, and then polishing that discharge with salicornia, brings total nitrogen recovery to approximately 90 percent in a closed-loop integrated multi-trophic system, meaning the small remaining fraction lost is close to the practical limit of what a biological system can recapture.

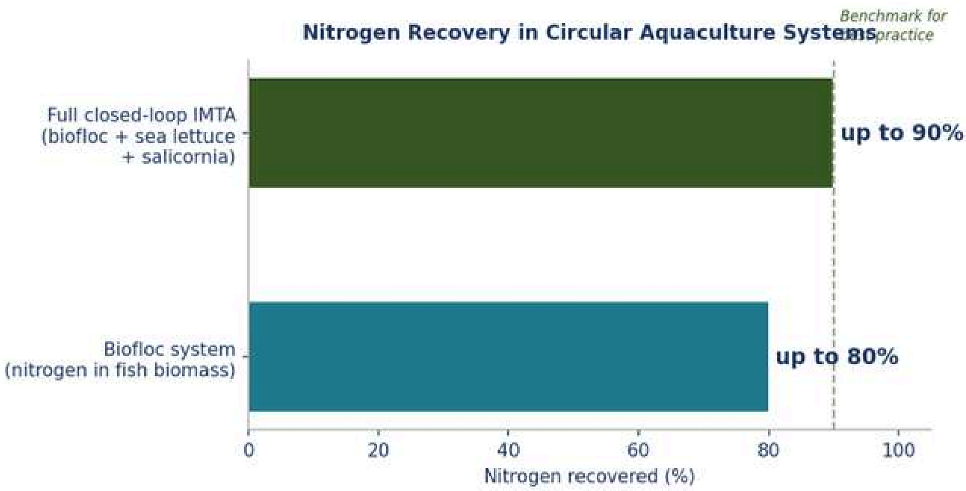


Figure 7. Nitrogen recovery in circular aquaculture systems. Source: Future Aquaculture, referencing a 2021 benchmarking study on nutrient circularity

The economic case reinforces the ecological one. Feed conversion in biofloc tilapia has been reported at 1:1 using a 20 percent protein feed, which represents a substantial cost saving because the floc itself supplies part of the nutrition, the microbial biomass functions as a second, in-tank feed source that a conventional system simply discards. This matters because it means the environmental gain is not achieved at a cost premium; on the feed line at least, it is achieved at a discount.

4.3 Resource Footprint: The Ghana Evidence

The resource savings reported from commercial operation in Ghana are of an order of magnitude that changes the economics of production, not merely its environmental profile. What previously required 100 acres of ponds is now produced from 5 acres of biofloc tanks, a twenty-fold reduction in land footprint. Water use has been reduced approximately thirty-fold. Because no water is discharged from the biofloc tanks, no nearby water body is polluted.

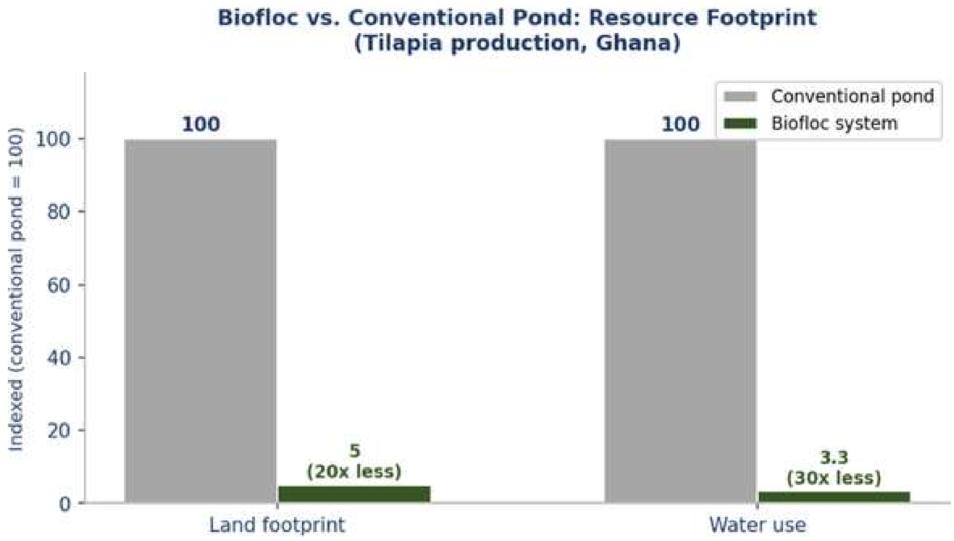


Figure 8. Biofloc versus conventional pond resource footprint, tilapia production in Ghana. Indexed to conventional pond = 100. Source: operator data, Volta Breams, Ghana.

The significance of this footprint reduction extends beyond the individual farm. Land and water are the two resources most often contested between aquaculture and competing land uses like agriculture, urban expansion, conservation. A twenty- to thirty-fold reduction in the footprint required to produce the same volume of fish changes the terms of that competition: it means aquaculture expansion no longer has to come at the direct expense of farmland or freshwater allocation in the way conventional pond systems require.

4.4 The Low-Hanging Fruit: Integrating Aquaculture and Agriculture

The separation of aquaculture from agriculture occurred through mechanisation and the spread of chemical fertilisers around the time of the Second World War. That separation created a structural inefficiency on both sides. Fish farms discharge nutrient-rich water that becomes a pollutant, while crop farms purchase chemical fertilisers that are expensive and depleting to soils. Bringing the two back together resolves both problems at once, because each system's waste is the other system's input.

The integration principle is straightforward. Source water is used for fish farming first; the nutrient-rich discharge water is then used for crop irrigation, displacing chemical fertiliser and loading organic matter and carbon into the soil. This addresses a further problem beyond farm-level economics: excess atmospheric carbon, and returning it to the soil carbon sink is one of the mechanisms available to mitigate that at scale, meaning this integration sits at the intersection of three separate policy priorities (water efficiency, fertiliser cost, and carbon sequestration) rather than serving only one.

The scale of the available opportunity is illustrated by the Western Cape of South Africa, which has 270,000 hectares under irrigation. If just 1 percent of the water consumed for irrigation were first passed through biofloc tanks for tilapia culture, the resulting fish production would be equivalent to the entire South African Cape Hake quota of 100,000 to 140,000 tonnes per year. That a 1 percent diversion of existing irrigation infrastructure, requiring no new water rights and no new land, could match an entire national wild-catch quota is precisely why this integration is characterized elsewhere in this report as the most immediately available opportunity in the sector: the water is already flowing, the irrigation infrastructure already exists, and the marginal step is a biofloc tank, not a new resource claim.

4.5 Zero-Discharge Systems at Commercial Scale

The most advanced systems combine several trophic levels in a single loop. In a zero-discharge marine system, biofloc tanks produce tilapia or mullet; the discharge flows to sea lettuce, which absorbs the nitrogen while producing a saleable crop; the discharge from the sea lettuce is polished by salicornia; 50 percent of the water is reused and the balance is lost to evaporation, achieving genuine zero discharge.

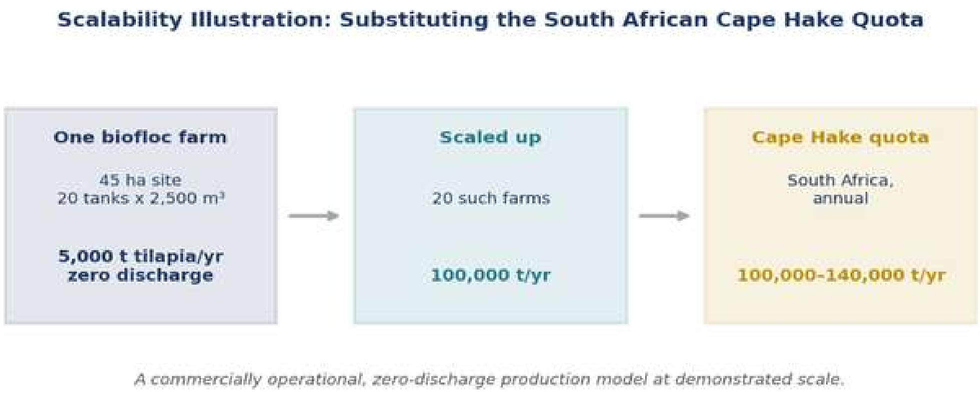


Figure 9. Scalability illustration presented in the dialogue: a commercially operating 45-hectare biofloc site and its implication at scale.

A further integration concerns the feed hierarchy. Tilapia grown on all-plant-based feeds in biofloc is processed into fillets; 65 percent of the fillet processing waste becomes a secondary-grade fishmeal suitable for feeding higher-trophic species such as Atlantic salmon, Asian sea bass, and yellowtail kingfish. This cascade reduces dependence on externally sourced fishmeal and on expensive alternative proteins such as insect protein and algal meals, while cutting transport logistics, in effect substituting a byproduct that would otherwise be discarded for an input the sector currently imports at cost. It has not yet happened at scale, and represents a significant unrealised gain: the biological pathway is proven, but the processing infrastructure to capture it commercially has not yet been built.

Restorative aquaculture completes the picture. Seaweed and shellfish cultivation are extractive: they feed themselves, and in doing so remove organic particles and nutrients from marine environments that are already oversubscribed with pollution. Expanding them provides a service to the ocean while producing food; the rare case in food production where scaling output and improving the surrounding ecosystem move in the same direction rather than trading off against each other.

We keep looking for the next breakthrough technology when the biggest gain in the sector is sitting in plain sight: the water that already runs through our irrigation canals. We don't need to invent aquaculture-agriculture integration. We need to stop treating it as optional."
—Ramon M. Kourie, Editor-in-Chief, Future Aquaculture Magazine, Aquaculture Technologist & Food Security Expert

5. Governance, Investment, and the Architecture of Transformation

5.1 The Priority Has Changed

For the past decade the priority in the blue economy was to create opportunities: investment in research, innovation, governance, and international cooperation. That was the right priority, and it produced remarkable progress. But the challenge has now changed. The question is no longer how to create opportunities. It is how to transform those opportunities into competitive industries capable of creating long-term economic value. This is a harder problem than the one it replaces, because creating opportunity rewards activity: a new research grant, a new pilot, a new partnership announced, while transformation rewards only outcomes that survive contact with a market.

Governance, investment, and collaboration should not be treated as separate priorities. They are complementary capabilities within the same economic system, each performing a distinct function, and each capable of undermining the others if it operates in isolation.

Governance creates the conditions under which transformation becomes possible, through legislation and aggregation. But it works only when organised around outcomes. Governance can create the conditions for growth; it cannot decree growth. Its role is to provide stability, reduce uncertainty, and create an environment in which companies and investors are willing to commit over the long term and startups are willing to innovate and compete. A government can build the enabling framework perfectly and still see no transformation, if nothing downstream converts that stability into commercial activity.

Investment does not flow because an idea is innovative, because of wishful thinking, or because a project is well intentioned. Capital flows after value creation. Investors allocate where they recognise business capability able to generate sustainable returns which means capital is a lagging indicator of transformation, not a leading one, and treating it as the trigger rather than the consequence is a category error that recurs throughout the sector.

Innovation is essential, but by itself it does not transform an economy. Research generates knowledge. Innovation expands what is possible. But companies are what transform knowledge and innovation into economic value. Transformation happens only when innovation is adopted, integrated into production, and rewarded by the market. A technology can be published, patented, and proven, and still change nothing, if no company carries it from the laboratory into a production line that a customer will pay for.

5.2 Why Technology Alone Does Not Transform the Blue Economy

Commercial adoption has become one of the most significant challenges facing the blue economy, more significant, on the evidence in Section 2, than the availability of proven technology itself. The role of governance, investment, and collaboration is therefore not simply to support innovation. It is to reduce the distance between scientific knowledge in universities and commercial adoption in the market, and to ensure that investments made are productive investments generating real returns. When these three elements reinforce one another, innovation reaches the market faster, companies become more competitive, and investment becomes easier to attract. When they operate independently, for instance, governance without a route to market, investment ahead of demonstrated value, innovation without a commercial owner each element can be individually healthy while the system as a whole stalls.

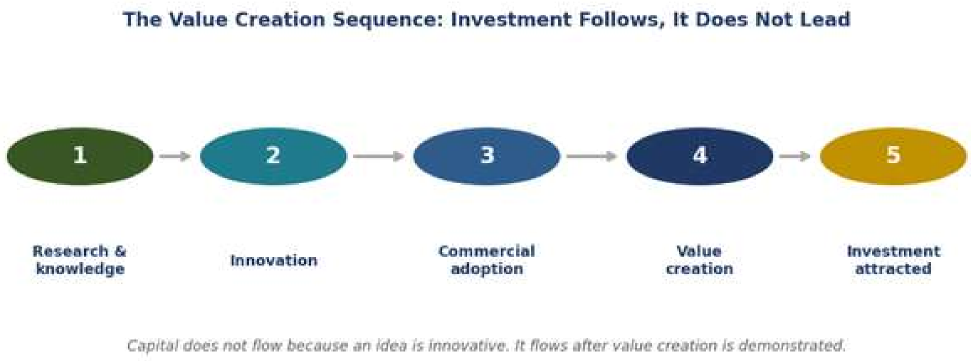


Figure 10. The value creation sequence as set out in the dialogue. Seeking capital before commercial value has been demonstrated is the common failure mode.

5.3 Making Innovation Investable

The assumption that the main barrier to scale is access to finance does not hold up against the evidence. Over the last decade, unprecedented amounts of capital have become available for climate, food systems, and sustainable development. If finance alone were the constraint, transformation would already be moving much faster, given how much capital has been sitting available and looking for a place to go. The real challenge is making innovation investable, that is, converting a proven technology into a business case an investor can underwrite.

The distinction between innovation and investment matters, and collapsing it is one of the most common strategic errors in the sector. Innovation creates new possibilities. Investment accelerates opportunities that are already capable of creating value. Capital will not invest in a technology simply because it is innovative; it invests in businesses that can adopt that technology, compete successfully, and generate sustainable returns. Value creation must come before financing. Investment follows value creation; it does not produce it which means a project seeking capital before it can demonstrate commercial value is, structurally, seeking the wrong thing at the wrong stage.

5.4 Partnerships Must Be Measured by Value, Not by Headcount

The same logic applies to partnerships. Too often, partnerships are measured by the number of organisations involved, as though breadth of participation were itself the achievement. They should be measured by the value they create together. Every successful industry combines different capabilities: research institutions generate knowledge; companies understand customers and markets; investors provide capital for growth; governments create stability and reduce uncertainty. The challenge is not bringing these organisations together, convening is comparatively easy. It is organising them around the same economic opportunity and the same agreed outcomes. Partnerships convened without that discipline produce the bystander effect: everyone is present, and no one is accountable. A room full of the right institutions, without a shared and specific outcome binding them, produces the appearance of progress rather than its substance.

5.5 Blue Clusters and the Territorial Logic

Many emerging market countries already possess extraordinary natural resources, scientific capability, talent, and interested communities, and are beginning to access international capital. What is lacking is not potential. Potential is not enough, a point that follows directly from Section 5.3: potential does not attract capital, demonstrated value does. Integration is what transforms these assets into productive businesses capable of attracting long-term private investment.

This is why clusters matter. A blue cluster is not simply a network for collaboration. It organises companies, universities, natural resource management, investors, and public institutions around a common economic opportunity. Scalable transformation is not about scaling projects, because a project is temporary. Industries endure, and the distinction is not semantic: a project has a funding cycle and an end date built into its design, while an industry, once it exists, keeps compounding on its own after the initial support is withdrawn.

The critical design principle is that every territory is different. Each has its own combination of natural resources, scientific knowledge, industrial capability, talent, and community aspiration. Each will therefore build a different blue economy and produce different economic outcomes. Sometimes the opportunity is not the fish; it may be the feed. The challenge is not to replicate the same model everywhere. India's model, described in Section 3, is not a template to be copied wholesale, but a demonstration of what sustained institutional commitment can achieve when matched to local conditions. The task for other territories is to help identify what can be globally competitive while also being right for their own capacity. If that is done successfully, food security and ecosystem health cease to depend on projects or on politics, and become the natural outcome of the territory, its resources, and its people.

> *A project ends when the funding does. An industry doesn't need permission to keep going, it just needs to be worth more tomorrow than it costs today. That's the only kind of transformation that outlasts the people who started it."*
> *—Pedro Bobião, Managing Director, Vide de Grunwald, Blue Economy & Innovation Ecosystems Expert*

6. Producers, Communities, and Infrastructure: The African Lens

6.1 The Cost Reality

A common assumption about sub-Saharan African markets is that costs are lower and that this constitutes a competitive advantage. Nineteen years of operating experience in Ghana points to the opposite conclusion. Almost every commodity required for production costs substantially more in Ghana than elsewhere, frequently two to three times more and in some cases six times more. The cost of production is consequently so high that exporting to international markets, where competition comes principally from Asian producers operating at a fraction of the cost, is not viable. This is worth stating plainly because it inverts the standard development-economics assumption: low labour costs are often treated as sufficient to offset other disadvantages, but where the disadvantage is in capital goods, energy, and imported inputs rather than labour, that offset does not materialise.

Electricity is the dominant input cost. Power costs in the region are among the highest in the world relative to purchasing power, and supply is unreliable. This affects aeration, water circulation, cold storage, processing, and market access, which is to say every stage of the value chain, meaning a single input, power, does not just raise costs at one point in production but compounds across the entire chain from tank to market.

6.2 Energy as the First Infrastructure Priority

The highest-leverage infrastructure investment for enabling smallholder aquaculture in the region is solar energy, delivered through reward-based financing. Solar investment can reduce power costs to approximately one quarter of current levels. That single change makes cold chain investment viable, lowers the cost of running biofloc and recirculating systems, and brings smallholder production costs within a competitive range. The leverage here follows directly from the diagnosis in 6.1: because power costs propagate through every downstream stage, fixing the power constraint does not solve one problem among many, it loosens the binding constraint on several problems at once, which is precisely why it is identified as the first infrastructure priority rather than one of several equally weighted options.

The reward-financing structure matters as much as the technology choice. Financing whose terms improve as measurable environmental or social outcomes are achieved aligns investor incentives with the outcomes the sector needs. It is more durable than grant funding, which is bounded by project timelines and therefore reproduces the design-for-adoption problem described in Section 2; value that disappears when the project ends and it is better suited than standard commercial lending, which does not price the public goods created by reduced emissions and improved food security. Reward-based structures, in effect, are an attempt to make an investment instrument that behaves like an industry rather than a project.

6.3 The Cold Chain Gap and the Price Paradox

The absence of cold chain infrastructure at farm, market, and distribution levels destroys economic value at every stage. Without ice and cold storage at the farm, post-harvest losses to spoilage are significant. In major African markets, fish is frequently sold without ice or cold storage, which depresses both consumer confidence and price. Without distribution cold chain, market reach is confined to the immediate vicinity of production, a producer's addressable market is set not by demand but by how far a fish can travel before it spoils.

The consequence is a precise price paradox: consumers feel that fish is expensive, while farmers feel they are not receiving an adequate price. Both are right, and the paradox resolves once the missing middle is identified. Value that should exist in the product is being destroyed by spoilage and extracted by intermediaries, and neither end of the chain captures it the money consumers pay is not reaching farmers, and it is not because farmers are being paid fairly and consumers are being overcharged; it is because a meaningful share of the product's value never survives the trip between them. Cold chain infrastructure from farm to market, combined with cooperative markets and auction centres that reduce middleman extraction, would allow consumers to pay less and farmers to receive more simultaneously, because the gain comes from recovering value currently being destroyed, not from redistributing a fixed amount between the two ends of the chain.

6.4 Communities as Growth Engines

The operating model converts infrastructure investment into community economic development. Where biofloc tanks are established in communities with reliable energy and cold chain, they can supply live fish into local urban markets, which is the highest-value product form available where cold chain is absent, live fish requires no cold chain to sell at a premium, which makes it a rational first product for exactly the communities described in 6.3 that lack distribution infrastructure. Women in those communities can take on fish-mongering roles, building enterprises that generate income and multiply economic activity locally.

Corporate social responsibility is better understood here as structural design than as charitable addition. Every company should formulate a comprehensive CSR programme, budget for it, and implement it, so that the local community becomes a stakeholder in the project rather than a bystander to it. Where sharing and caring genuinely happen, communities participate in aquaculture projects and, in doing so, increase the security of production. This addresses one of the persistent barriers to expansion in West Africa: community opposition to operations that extract value without sharing it. The logic is not primarily ethical, though it is that too, it is operational. A community with a stake in a farm's success protects that farm; a community that experiences the farm only as an outside extraction has no reason to.

A competitive blue economy is built not by producing more fish alone, but by building infrastructure and value chains that keep value between the farm and the market, so that farmers earn more, consumers pay less, and communities thrive."
— Naga Murali Chalamalasetti, Managing Director, Volta Breams Ltd

7. Cross-Cutting Themes

7.1 The Equity Imperative

Equity is not a peripheral consideration layered onto this report's analysis; it is a structural dimension of the argument itself, and it runs through every section above. Small-scale fishers, coastal communities, women, and emerging producers are not peripheral actors in aquatic food systems. They are foundational to how those systems function in many regions, the shrimp export figures in Section 3, for instance, are underpinned by the fact that 95 percent of that production comes from smallholders farming one to five hectares. Yet they remain structurally underrepresented in investment, governance, and value chains.

The sharpest statement of the problem is this: a transition that does not include them is not a transition. It is a reconfiguration of existing imbalances under a new technical vocabulary. The exclusions are not incidental; they are built into the architecture of how the sector currently allocates capital and access. Value chains designed around large-scale export require certifications and volumes smallholders cannot supply. Cold chain concentrated in export processing does not serve local markets, the same cold chain gap described in Section 6 that depresses domestic prices while raising consumer costs. Investment criteria optimised for commercial scale exclude artisanal operations by design, since the underwriting logic described in Section 5 rewards demonstrated value at a scale most smallholders will never individually reach. Closing this gap therefore is not a matter of adding a smallholder-inclusion clause to existing instruments; it requires value chains, cold chain networks, and investment criteria built around smallholder economics from the outset, in the same way Section 2 argues that adoption has to be a design criterion rather than an afterthought.

7.2 Ecological Limits

Over one-third of global fish stocks remain overexploited. Aquaculture expansion, intended in part to relieve pressure on wild stocks, brings its own pressures, particularly around feed inputs, land use, and environmental externalities. Some aquaculture supply chains rely heavily on agricultural inputs such as soy, which links ocean-based food production to land-use change, deforestation, and freshwater demand elsewhere in the world, meaning a sector that markets itself as an alternative to overfished wild capture can, depending on how it sources feed, simply relocate ecological pressure from the ocean to the land rather than eliminating it.

Seaweed illustrates the alternative. It requires no fresh water, no arable land, and minimal external inputs, while contributing to nutrition, climate mitigation, and ecosystem services. The question is not whether such solutions exist, but how to scale them in ways that are economically viable, socially inclusive, and ecologically responsible, the same diffusion problem identified in Section 2 applied to a different technology. A biologically ideal solution that never leaves the demonstration stage delivers none of its ecological promise; the ecological case for seaweed is only as strong as the sector's ability to solve the adoption and investment problems described earlier in this report.

7.3 Food Safety and Emerging Contaminants

The safety of aquatic food products is an increasing concern in the context of emerging pollutants, and microplastics in particular, which are now reported across species and geographies. This is a global concern extending well beyond the food production sector, since aquaculture uses water that is polluted by activities upstream of it, aquaculture is in this sense a downstream inheritor of pollution rather than its primary source, which complicates both the assignment of responsibility and the design of an effective response. International guidelines and Codex standards are improving to support countries in establishing food production standards and codes of conduct. How these normative instruments reach countries with limited enforcement capacity remains unresolved, and this gap matters in proportion to how much of future production growth is expected to occur in exactly those countries: a standard that exists on paper but cannot be enforced at the point of production does not protect the consumer it is written for.

7.4 What International Organisations Can and Cannot Do

For countries such as Somalia and Cameroon, where the national research, governance, and private sector infrastructure that India built over 75 years does not yet exist, the relevant question is what international organisations can realistically contribute to closing that gap. The answer describes a specific and bounded role, not a substitute for the missing infrastructure itself.

International organisations such as FAO function as a knowledge centre: supporting members to develop their own national policies, extension systems, and technology deployment; providing normative frameworks such as the Guidelines for Sustainable Aquaculture; and working through national authorities rather than around them.

For a country such as Somalia, this translates into a fact-finding mission to identify the resources and areas suitable for food production, followed by a holistic strategy built on national and local resources rather than an imported template. On private sector engagement, the operating principle is that UN agencies work with national authorities, and that the private sector and small-scale farmers and fishers sit at the centre of the programmes they initiate rather than at its periphery.

The implication is that international organisations are well positioned to convene, to translate knowledge across borders, to provide normative frameworks, and to facilitate South-South transfer of the kind demonstrated by Indian aquaculture expertise operating in Ghana. They are not positioned to substitute for the sustained national public investment, private sector development, and community-level infrastructure that are the actual engines of transformation described throughout this report. This is a meaningful distinction for policy design: it means the realistic ask of international bodies is knowledge brokerage and normative scaffolding, while the harder, slower work of building institutions, mobilising domestic capital, and developing local enterprise remains a national responsibility that no external organisation can perform on a country's behalf.

7. Recommendations

7.1 Align National Policy with the FAO Guidelines for Sustainable Aquaculture

Primary actors: national governments, regional economic communities, FAO.

Governments should integrate national aquaculture policy with the Guidelines for Sustainable Aquaculture adopted at the 36th session of the Committee on Fisheries in 2024. The Guidelines span policy and governance, on-farm and resource management, social dimensions including gender, women and youth, and the value chain. Each country should develop a costed, time-bound action plan that provides an enabling environment, addresses the conservation and utilisation of aquatic genetic resources, and integrates responses to climate change and biosecurity. This is the governance function described in Section 5: policy that is organised around measurable outcomes rather than around process, and that creates the conditions for transformation without attempting to substitute for it.

7.2 Sustain long-term public investment in research infrastructure

Primary actors: national governments, national research institutions, development finance institutions.

India's experience demonstrates that project-based research funding cannot substitute for long-term institutional investment. Governments with significant aquaculture potential should establish or strengthen dedicated research institutes, sustain funding across political cycles on multi-decade time horizons, and build the convergence between government, research institutions, and industry that made India's transformation possible. Public investment is a necessity; private investment alone will not deliver it, because the returns to foundational research and disease surveillance accrue to the sector as a whole rather than to any single investor, and are consequently undersupplied by private capital acting alone.

7.3 Focus on indigenous species rather than importing species models

Primary actors: national research institutions, ministries of fisheries and aquaculture.

Each country should identify and develop the aquaculture potential of its own indigenous species rather than adopting the species portfolio that has succeeded elsewhere. Each country should identify its own potential species, and build the breeding and farming technology around them, rather than importing a model calibrated to a different climate, market, and resource base. This follows directly from the diffusion diagnosis in Section 2: what transfers between regions is capability and method, not necessarily the specific species portfolio that method was first applied to.

7.4 Develop production clusters

Primary actors: national governments, regional development agencies, private sector anchors.

Cluster development is a specific and transferable mechanism. India's example of a single freshwater cluster covering 100,000 hectares, farmed continuously for 30 years, demonstrates the scale that sustained cluster-based development can reach. Clusters concentrate extension services, input supply, processing, and market access, and make investment in shared infrastructure economically rational at a scale no individual smallholder could justify alone, directly addressing the design-for-adoption problem in Section 2.2, since a cluster structure allows complex support systems to reach farmers who could not access or afford them individually.

7.5 Mainstream circular and zero-discharge production

Primary actors: national governments, private operators, development finance institutions.

The transition from open-discharge pond aquaculture to closed or near-closed systems should be actively promoted through regulatory incentive and public co-investment. Biofloc technology and integrated multi-trophic aquaculture are commercially proven and scalable, as demonstrated in Section 4. Priorities are: integration of fish farming into existing agricultural irrigation systems, the single most immediately available opportunity in this sector given that it requires no new water rights or land allocation; integration of low-trophic and high-trophic species on the same farm to close the feed loop; expansion of restorative seaweed and shellfish aquaculture; and a shift to renewable energy to reduce the carbon footprint of production.

7.6 Prioritise energy and cold chain infrastructure in emerging markets

Primary actors: national governments, development finance institutions, private energy and infrastructure investors.

In sub-Saharan Africa, reward-based financing for solar energy investment supporting aquaculture farmers is the highest-leverage infrastructure entry point, capable of reducing power costs to approximately one quarter of current levels, with cascading cost reductions across cold storage, aeration, and processing as set out in Section 6. Cold chain infrastructure, with ice plants and cold storage at farm, market, and distribution levels, is the second priority. Both should be paired with cooperative markets and auction centres that allow farmers to reach buyers without value being extracted by intermediaries. Financing instruments should be structured on reward-based rather than pure grant or standard commercial terms, for the reasons set out in Section 6.2: reward-based structures outlast project funding cycles and price the public good created by lower emissions and improved food security in a way standard commercial lending does not.

7.7 Build value chains that serve both producer and consumer

Primary actors: private operators, cooperative and market institutions, national governments.

Value chains should be restructured so that the gap between what consumers pay and what farmers receive narrows not through redistribution between the two, but through recovery of the value currently destroyed by spoilage and extracted by unnecessary intermediation, as described in Section 6.3. This requires cooperative markets, auction centres, and community market structures. Corporate social responsibility programmes should be formulated, budgeted, and implemented by every operating company as a component of production risk management, not as a discretionary add-on, so that local communities become stakeholders in production security rather than bystanders to extraction.

7.8 Align partnerships and clusters with commercial and economic outcomes

Primary actors: convening institutions, national governments, private sector, investors.

Partnerships should be measured by the value they create, not by the number of organisations they contain; convening breadth is not itself an outcome. Innovation ecosystems should also be assessed by commercial adoption. Patents, pilots, research programmes and startups indicate activity, but impact ultimately depends on whether innovations are adopted by companies, integrated into production and generate measurable economic value. Development programmes should begin by identifying each territory's specific competitive advantage which, as Section 5.5 notes, may differ by territory and need not be fish production itself and organise research institutions, companies, investors and public institutions around that opportunity with clear accountability. Capital should be sought after value creation has been demonstrated, not before, consistent with the sequencing set out in Section 5.3.

7.9 Respect local sovereignty over food systems

Primary actors: international organisations, donor governments, development finance institutions.

International support must respect local agricultural knowledge and empower smallholders rather than imposing external solutions. Developing countries should not be passive recipients of food system models designed elsewhere; the role of international organisations, as set out in Section 7.4, is to convene, to broker knowledge transfer, and to provide normative frameworks not to substitute for domestic institution-building. Where technology transfer occurs, it should be structured to build local capacity and local ownership rather than create ongoing dependency on external technical support, financing, or inputs.

Conclusion

This report opened with a paradox: a sector that has never been more capable, facing a growth trajectory that is decelerating just as the world needs it most. Having worked through the evidence, from India's seventy-five-year institutional build, to Ghana's closed-loop tanks, to the irrigation canals of the Western Cape that could quietly rival a national fishing quota, the paradox resolves into something more specific and more actionable than it first appeared. This is not a sector short on solutions. It is a sector that has not yet built the architecture to move its own solutions to where they are needed.

That distinction matters because it changes what kind of effort the next decade requires. A knowledge shortage is solved by more research. A capital shortage is solved by more financing. The shortage this report identifies alignment between what works, who has it, who needs it, and who can pay for it to travel is solved by neither. It is solved by governments willing to fund institutions on a multi-decade horizon rather than a project cycle; by investors willing to let value creation lead and capital follow, rather than the reverse; by companies willing to treat the communities they operate in as co-owners of production security rather than as a cost of doing business; and by international organizations willing to define their role honestly, as brokers of knowledge and normative frameworks rather than substitutes for the domestic institution-building that only national governments can do.

None of this is a call for more ambition. The sector already has ambition in surplus; every region examined in this report has its own version of a plan to double, triple, or quadruple production. What it needs is discipline: the discipline to make the boring infrastructure investment before the exciting one, to measure partnerships by the outcomes they produce rather than the logos on the agenda, and to design the next technology for the farmer who will actually use it, not the one who published the paper.

The sector's growth curve will not wait for that discipline to arrive on its own. Whether the next twenty years of aquaculture repeat the achievements of the last twenty, or fall short of them, will be decided less by what gets discovered in a laboratory than by what gets built between the laboratory and the farm. That is the work this report has tried to describe. It is also, as discussed, entirely within reach.

Annex A. Speaker Profiles

This report draws on perspectives shared by the following contributors, whose insights inform the analysis presented throughout. Affiliations are listed as they appear at the time of contribution.

Dr Alix Willemez is an Expert of World Ocean Assessment II & III, United Nations. She has spent over two decades working at the intersection of aquaculture policy and food systems finance, advising national governments and multilateral institutions on the design of blue economy strategy. Dr Alix's work focuses on the gap between technical feasibility and institutional adoption and has led field-based reviews of aquaculture programs across South and Southeast Asia and sub-Saharan Africa.

Xinhua Yuan is the Deputy Director, Fisheries and Aquaculture Division, FAO, Rome. Over 30 years of experience in aquaculture research, management, and international development. Led the development of the FAO Guidelines for Sustainable Aquaculture and the Blue Transformation roadmap implementation. Presented the global perspective on production, governance, and the systemic gap.

Ramon M. Kourie is a veteran aquaculture engineer and practitioner from South Africa, with nearly four decades of experience in sustainable fish farming systems across Africa and the Middle East. He is the Editor-in-Chief of Future Aquaculture, a newly launched international peer-reviewed quarterly journal published by Green Wave Publication, which aims to advance scientific knowledge and technical innovation across the global aquaculture sector.

Pedro Bobião is Founder and Managing Director of Vide de Grunwald, an Operating Partners and M&A firm focused on execution, investment and value creation. With more than two decades of experience leading businesses, executing investments and supporting companies across Europe, the Americas, Africa and Asia, his work in the Blue Economy focuses on bridging innovation, capital and commercial adoption, with particular emphasis on territorial ecosystems and blue clusters

Dr. Joykrushna Jena is the Deputy Director General (Fisheries Science), ICAR – Indian Council of Agricultural Research, New Delhi, India. He is one of India's most eminent fisheries scientists. He also served concurrently as DDG (Animal Science) from April 2017 to January 2020, overseeing India's entire animal science research portfolio. He spent the formative years of his research career at the ICAR-Central Institute of Freshwater Aquaculture (CIFA), Bhubaneswar, rising through the ranks to serve as ICAR National Fellow and Head of Division, where he contributed foundational technologies in carp breeding, seed production, aquaculture diversification, and intensive fish culture systems.

Naga Murali Chalamalasetti is the Managing Director of Volta Breams Ltd, a leading aquaculture company based in Ghana, West Africa, specialising in Tilapia hatchery operations, grow-out systems, and aquaculture consultancy services.
With over three decades of hands-on experience across India, Africa, and international markets, Naga has held senior roles at Triton Aquaculture Africa Ltd, Nimba Fish Farm, and Mansvi Fisheries Private Limited, among others. He co-founded Volta Breams Ltd in 2013 alongside his wife, initially launching a cage culture farm on Lake Volta in Ghana and subsequently establishing an on-site hatchery aimed at producing up to 16–20 million high-quality Tilapia fingerlings per year.

Recording Link:

https://youtu.be/uzm1EIRqvok?si=kQCS6yFbAuzRhAPe

Annex B. Data Cited in the Dialogue

Every figure below was stated by a participant during the dialogue. No figure has been supplied from any other source.

Global Production and Employment

Indicator	Value	Source
Global aquatic food production, 2024 (record)	142 million tonnes	*FAO*
Aquatic animals within that total, 2024	103 million tonnes	*FAO*
Aquaculture annual growth rate since 2000	4.9 percent per year	*FAO*
Direct employment in fisheries and aquaculture	60 million people	*FAO*
Livelihoods dependent on the value chain	600 million people	*FAO*
Asia's share of farmed aquatic animal production	Approximately 90 percent	*FAO*
Targeted increase in African aquaculture production	Approximately 75 percent	*FAO*
Global fish stocks overexploited	Over one-third	*our world in data organization*
Aquaculture growth rate, 2012 to 2022	4.0 percent per year	*FAO*
Aquaculture growth rate projected, 2022 to 2032	1.6 percent per year	*FAO*

India

Indicator	Value	Source
Position 40 years ago	8th largest producer	*ICAR*
Current position	2nd largest fish and aquaculture producer	*ICAR*
Production, historic baseline	Less than 1 million tonnes	*ICAR*
Current production	Approximately 19.75 million tonnes	*ICAR*
Production vision for 2047	40 million tonnes	*ICAR*
Of which from aquaculture, 2047	Approximately 32 million tonnes	*ICAR*
Research institutes established 1947	2 (marine and inland)	*ICAR*
Fishery research institutes today	8	*ICAR*
Farmed species, historic	68	*ICAR*
Farmed species today	More than 80 to 90	*ICAR*
Selective breeding programme duration	35 years continuously	*ICAR*
Carp hatcheries	More than 3,000	*ICAR*
Shrimp hatcheries	More than 500	*ICAR*
Disease surveillance programme duration	15 years	*ICAR*
Fish and fishery product exports	Approximately USD 8.3 billion per year	*ICAR*
Shrimp share of exports	Approximately USD 5 billion	*ICAR*
Share of potential production area in use	Approximately 15 percent	*ICAR*
Share of shrimp production from small and marginal farmers	95 percent	*ICAR*
Largest freshwater farming cluster	100,000 hectares, farmed 30 years	*ICAR*

Production Technology and Circularity

Indicator	Value	Source
Nitrogen recovered in biofloc tilapia biomass	Up to almost 80 percent	*Future Aquaculture*
Nitrogen recovery, full closed-loop IMTA	Approximately 90 percent	*Future Aquaculture*
Feed conversion ratio, biofloc tilapia (20% protein feed)	1:1	*Future Aquaculture*
Water reused in zero-discharge marine system	50 percent (balance lost to evaporation)	*Future Aquaculture*
Commercial biofloc site	45 hectares, 20 tanks of 2,500 m^3	*Future Aquaculture*
Output of that site	5,000 tonnes tilapia per year, zero discharge	*Future Aquaculture*
Farms needed to replace SA Cape Hake quota	20	*Future Aquaculture*
South African Cape Hake quota	100,000 to 140,000 tonnes per year	*Future Aquaculture*
Western Cape area under irrigation	270,000 hectares	*Future Aquaculture*
Irrigation water diversion needed to match Cape Hake	1 percent	*Future Aquaculture*
Fillet processing waste convertible to fishmeal	65 percent	*Future Aquaculture*
Biofloc land footprint vs conventional pond	100 acres reduced to 5 acres (20x)	*Volta Breams*
Biofloc water use vs conventional pond	Approximately 30x reduction	*Volta Breams*
Input cost inflation, Ghana vs other markets	2 to 3x, in some cases 6x	*Volta Breams*
Power cost reduction achievable through solar	To approximately one quarter	*Volta Breams*
Major players dominating the Ghanaian industry	4	*Volta Breams*

Annex C. Glossary

Blue Economy	The use of ocean and aquatic resources for economic growth, livelihoods, and jobs while preserving the health of the aquatic ecosystem.
Blue Cluster	An organised territorial economic system bringing together companies, universities, natural resource management, investors, and public institutions around a shared and specific competitive opportunity. Distinguished in the dialogue from a simple collaboration network.
Biofloc Technology	A production system in which bacterial communities (floc) in the water column absorb dissolved nitrogen and convert it into microbial biomass, which filter-feeding fish such as tilapia consume directly. Reduces feed cost, removes the need for water exchange, and achieves near-zero discharge.
Blue Transformation	FAO's roadmap for transforming aquatic food systems to be more productive, inclusive, resilient, and sustainable.
Cold Chain	A temperature-controlled supply chain from production through processing, transport, storage, and retail. Its absence was identified as a major driver of post-harvest loss and depressed prices in African markets.
Codex Alimentarius	The internationally recognised collection of food standards, codes of practice, and guidelines, published by the FAO/WHO Codex Alimentarius Commission.
Eutrophication	The over-enrichment of a water body with nutrients, typically from agricultural or aquaculture effluent, producing algal growth that depletes oxygen and damages biodiversity.
Integrated Multi-Trophic Aquaculture (IMTA)	A system combining species from different trophic levels so that the waste of one becomes the nutrient input of another, maximising nutrient recovery and minimising discharge.
Reward Financing	A financing structure in which the terms of capital improve as measurable environmental or social outcomes are achieved, aligning investor return with sustainability outcome.
Rubisco / Salicornia	Salicornia is a genus of salt-tolerant succulent plants able to grow in marine aquaculture effluent, absorbing nitrogen while producing a saleable halophyte crop. Used as the polishing stage in zero-discharge systems.
Sea Lettuce	A green macroalga (Ulva species) used as an extractive species in integrated systems, absorbing dissolved nitrogen from aquaculture discharge while producing a marketable crop.
Value Chain	The full sequence from input supply through production, processing, distribution, and retail. Its structure determines whether smallholder producers capture a fair share of the value created.

Annex D. Source and Contact Information

Source

This report is informed by the insights, perspectives, and discussions shared during the policy dialogue. Quotations and contributions have been transcribed and lightly edited for clarity and readability while preserving their original intent. The analysis, synthesis of key themes, interpretations, and resulting recommendations are the responsibility of the World Agriculture Forum Policy Unit.

Contact

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About the World Agriculture Forum

WAF is a global platform connecting diverse stakeholders to drive sustainable agricultural development through policy advocacy, trade facilitation, and technology-driven solutions. WAF unites governments, farmers, agribusinesses, experts, and development institutions to bridge implementation gaps and drive sustainable agriculture and food systems transformation towards a resilient, food-secure future. With a strong focus on collaboration, innovation all along the value chain, and public-private partnerships, WAF is committed to transforming agriculture worldwide.

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