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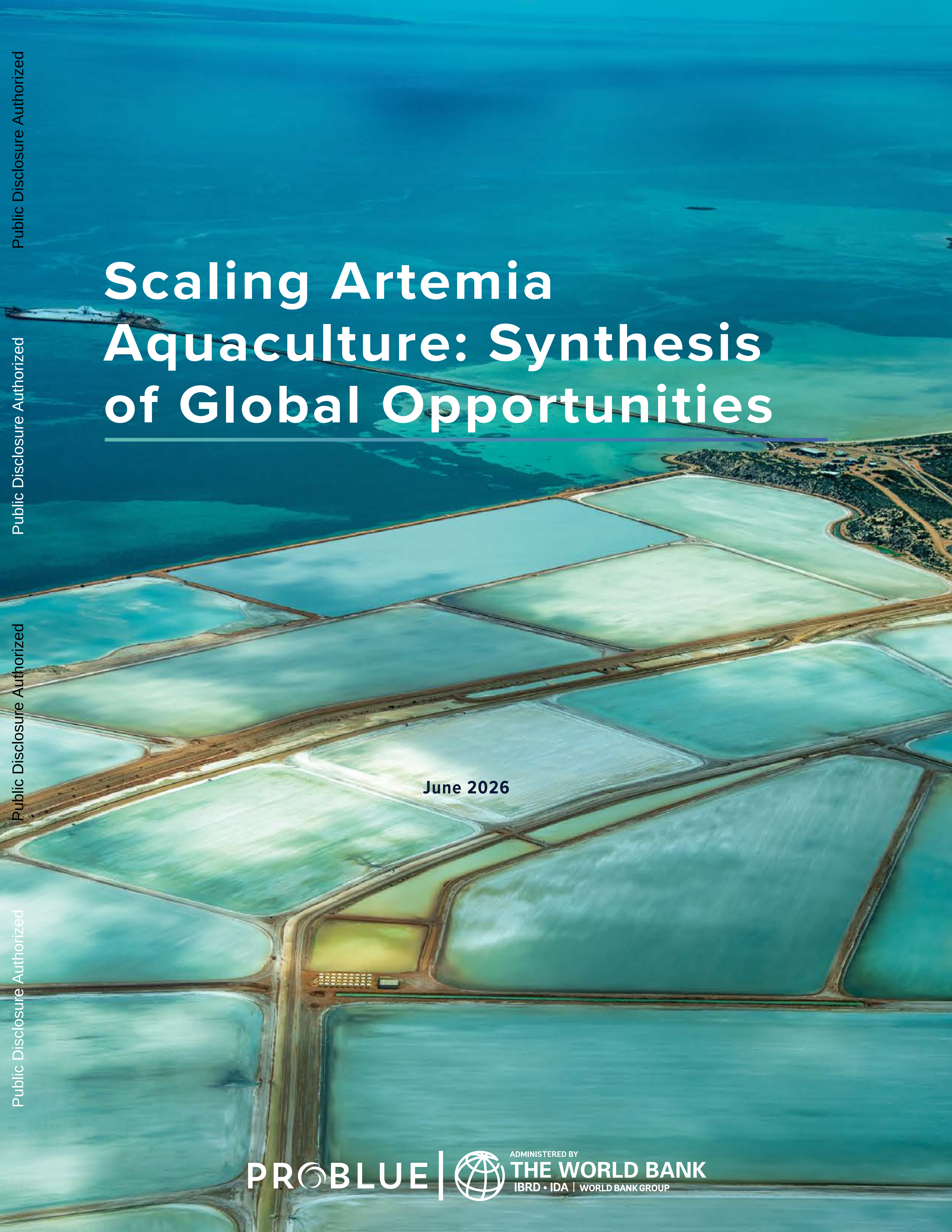

Scaling Artemia Aquaculture: Synthesis of Global Opportunities

June 2026

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GLOSSARY

Artemia biomass: Live, mainly adult Artemia, which may be bulk harvested for use as animal feed or human food.

Compound feeds: Formulated animal feeds made by combining animal proteins, fats, grains, proteins, vitamins, and minerals into balanced diets for livestock, often in pellet or granule form.

Cyst: A dormant Artemia embryo encased in a protective shell, capable of surviving harsh conditions for decades. Produced when habitats dry up, cysts can be stored long-term and hatch into nauplii within 24 hours under suitable conditions. They are a key aquaculture feed and the primary traded Artemia product.

Cyst separation: The process of removing empty cyst shells from newly hatched Artemia nauplii, typically using methods like sieving or magnetic separation systems.

Decapsulation: Removal of the hard outer shell of Artemia cysts, typically using a chemical process. This allows cysts to be used as a direct feed without the need for hatching.

Enrichment: The process of enhancing the nutritional profile of live feeds, such as Artemia nauplii, by feeding them with nutrient-rich substances before they are provided to aquaculture species.

Gene (cyst) bank: A repository for storing genetically diverse Artemia cysts of different species and strains under controlled conditions to preserve genetic resources for future breeding, research, and aquaculture use.

Integrated livelihoods: A holistic approach to improving rural livelihoods by combining aquaculture, agriculture, and other income-generating activities to enhance food security, economic resilience, and sustainable resource use.

PROBLUE: An umbrella multi-donor trust fund administered by the World Bank that supports sustainable and integrated development of marine and coastal resources in healthy oceans.

Solar saltworks: Facilities where salt is produced through the evaporation of seawater or brine in shallow ponds using solar energy, often providing a habitat for Artemia populations.

ACRONYMS

ASA	Advisory Services and Analytics (World Bank)
EPA	Eicosapentaenoic Acid
FAO	Food and Agriculture Organization of the United Nations
GSL	Great Salt Lake
IAAC	International Artemia Aquaculture Consortium
IAQ	INVE Aquaculture
IoT	Internet of Things
NACA	Network of Aquaculture Centres in Asia-Pacific
NGO	Nongovernmental Organization
PPP	Public-Private Partnership
QA	Quality Assurance
R&D	Research and Development
RDI	Recommended Daily Intake
ROI	Return on Investment
SMEs	Small and Medium Enterprises
TTL	Task Team Leader

EXECUTIVE SUMMARY

This synthesis report consolidates over half a year's worth of technical research, market analysis, and country-level value chain assessments to present a comprehensive investment overview of the brine shrimp—Artemia—aquabusiness. Developed as part of the World Bank's PROBLUE initiative on sustainable aquaculture and blue economy development, the report draws together the findings of six assessments, covering Artemia production systems, governance frameworks, markets and trade, emerging use cases, inventories of innovators, and in-depth country value chain studies.

Artemia, or brine shrimp, is a cornerstone input in hatchery-based aquaculture—used in the early life stages of shrimp, marine fish, and increasingly, ornamental species. However, over 90 percent of the global Artemia cyst supply is still derived from wild sources, primarily from hypersaline lakes in the United States and Central Asia. This dependence exposes the Artemia aquabusiness to supply shocks, price volatility, and environmental risks. Meanwhile, demand for Artemia is rising rapidly in response to global aquaculture growth and the search for sustainable, climate-smart solutions for animal feed and human food.

The purpose of this synthesis report is to

- Provide an integrated overview of the current state and future potential of farmed Artemia systems,
- Present investor-ready intelligence on country contexts, production models, and enabling conditions, and
- Guide strategic decision-making across public, private, and donor stakeholders through a concise but data-driven road map for investment and scale.

The report builds on field-level insights and technical models drawn from in-depth value-chain analyses in five countries—Bangladesh, Viet Nam, Thailand, China, and Kenya—and a broader investment readiness scan across 27 additional countries identified as high-potential scaling candidates. Using structured criteria around market demand, resource availability, governance, inclusion, and scalability, the synthesis distills lessons into four scalable Artemia business models and presents regional investment road maps for Asia, Africa, Latin America, and the Middle East.

The Artemia Opportunity

- Artemia is the foundation of the global hatchery industry—feeding shrimp, marine finfish, and ornamental species—but over **90 percent of supply still comes from wild lakes,** mainly the Great Salt Lake (GSL, United States) and Central Asia.
- Global production of Artemia cysts stands at **~3,500 tonnes per year, worth USD 200 million**, while the total industry (including biomass and processing) exceeds **USD 400 million annually**.
- Demand is rising with global aquaculture growth. By 2035, hatcheries alone could require **more than 5,000 tonnes of cysts per year**, while new biomass and human-food markets could expand the addressable market to **USD 500–600 million**.

Only **~10 percent of Artemia cysts are farmed**, creating an immediate investment gap equivalent to one additional GSL.

Commercial Viability and Scale Potential

- Proven farming systems in **China, Viet Nam, Thailand, and Bangladesh** achieve **150–300 kg of cysts per hectare per year** and **2–5 tonnes of biomass per hectare**, depending on management intensity.
- **Production costs (USD 40–80 per kg of cyst)** are already competitive with imports, while gross margins of **USD 3,000–7,000 per ha per season** deliver **returns above 25–30 percent,** when clusters exceed 30–40 ha.
- Pilot investments in Asia show **payback periods under three years**, supported by **low capex** (USD 500–3,000 per ha for salt pond retrofits) and shared infrastructure with existing saltworks.
- Converting just **10 percent of existing salt ponds** across high-potential countries could double global supply, supporting aquaculture independence and rural diversification.

Market and Trade Outlook

- The **Artemia cyst market** remains the premium segment (USD 30–200 per kg depending on hatchability and purity), but **biomass markets** are emerging rapidly as live, frozen, or dried feeds for aquaculture, livestock, and pets.
- **A tonne of Artemia cysts supports production of ~4,000 tonnes of shrimp**—demonstrating extraordinary leverage per input unit.
- Africa currently imports over **1,000 tonnes of cysts annually**, representing a **USD 70–90 million regional import bill**—a clear substitution opportunity through domestic production.
- **Latin America and the Middle East and North Africa** have large-scale saltworks capable of Artemia integration, while **African nations** like Kenya, Senegal, Namibia, and Egypt offer saline land and strong aquaculture growth.

Social and Livelihood Impacts

- Artemia farming is **highly labor-intensive**: each hectare supports **2–3 full-time equivalent jobs** across pond operations, harvesting, and processing.
- In Bangladesh, smallholder participation increased **household incomes by 150 percent**, generating **USD 740 in net seasonal earnings per farmer** and improving food security during dry seasons.
- Women play central roles in cyst cleaning and biomass processing; women-led cooperatives now dominate pilot operations in Bangladesh and Viet Nam.
- **Inclusive cluster models** in saline-affected or degraded lands can create **significant rural employment**, especially for youth and women, while rehabilitating unproductive landscapes.

Environmental and Climate Resilience Benefits

- **Zero freshwater footprint:** Artemia thrives in hypersaline environments, often unfit for agriculture or aquaculture.
- **Low-carbon systems:** Solar drying and natural evaporation make Artemia one of the **lowest-emission proteins per kilogram of biomass** in global aquaculture.
- **Circular integration:** Dual-use salt-Artemia systems reuse brine, recycle nutrients, and rehabilitate saline-affected land.
- **Biodiversity co-benefits:** By reducing pressure on fragile natural salt lakes, farmed Artemia contributes to wetland conservation and migratory bird habitat protection.

Business and Investment Opportunities

1. Integrated Artemia-Salt-Aquaculture Systems

- **What:** Retrofit or co-develop Artemia ponds within existing solar saltworks and coastal aquaculture zones.
- **Why:** These areas already have hypersaline infrastructure, logistics, and market access—enabling dual-income streams from salt and Artemia while reusing brine and evaporation ponds.
- **Examples:** Bangladesh's salt-Artemia clusters and China's Bohai Bay saltworks demonstrate technical and economic viability, achieving **USD 6,000–30,000 per ha per year** and **30–50 percent profit margins**.
- **Scale potential:** Converting even **10 percent of underused salt ponds** across Asia and Africa could double global Artemia supply.
- **Investment model:** Public-private partnership (PPP) retrofits (public salt infrastructure + private operators) or small and medium enterprises (SME)/cooperative clusters for artisanal salt producers.
- **Social and environmental benefits:** Creates off-season employment, empowers women in processing, and rehabilitates saline lands without freshwater use.

2. Biomass-to-Feed Innovations

- **What:** Develop commercial Artemia biomass production for aquafeed, poultry feed, and pet-food markets.
- **Why:** Biomass adds stability and diversification—processed into pastes or powders that replace **5–10 percent of fish meal** in shrimp and fish diets with no performance loss.
- **Examples:** Viet Nam and Thailand convert **2–5 tonnes per ha per year** of biomass into feed ingredients; Bangladesh's artisanal systems yield **1–1.4 tonnes per ha per season**, doubling household incomes.
- **Innovation drivers:** Low-cost dryers and sieving units, enrichment (omega-3, selenium, vitamin A), and small-scale pelletizing for feed mills.
- **Investment needs:** Processing equipment, product research and development (R&D), and feed-mill partnerships to secure offtake.
- **Cross-sector links:** Reduces fish meal imports, strengthens regional feed security, and aligns with circular-economy principles.

3. Nutritional Access and Protein Models

- **What:** Use Artemia biomass as a fast-turnover, high-protein food for human consumption or humanitarian nutrition.
- **Why:** With **~60 percent protein** and essential fatty acids, Artemia can fortify food products and supplements in saline-affected or food-insecure areas.
- **Opportunities:** Pilot fortified powders and snacks in coastal Bangladesh and Kenya; integrate into nutrition and women's empowerment programs.
- **Impact logic:** Positions Artemia as a **climate-resilient protein** where conventional aquaculture or livestock cannot thrive.

Cross-Cutting Enablers

- **Policy anchoring:** Formally recognize Artemia aquaculture and include it in blue economy and salt-sector strategies.
- **Certification and quality assurance (QA):** Develop hatch-out testing, traceability, and national quality standards; traceable cysts can command **30–50 percent price premiums**.
- **Anchor partnerships:** Link production to hatcheries, feed mills, and cooperatives to ensure steady markets.
- **Finance mechanisms:** Use blended-finance tools—guarantees, concessional credit, and challenge funds—to de-risk early entrants.
- **Inclusion and gender:** Prioritize women-led and youth enterprises through micro-finance and training.
- **Climate and natural-capital framing:** Integrate Artemia into saline-land rehabilitation and adaptation programs aligned with Nationally Determined Contributions (NDCs).

Sequencing for Scale

- **Scoping and stakeholder engagement:** Identify sites, private partners, and national champions.
- **Platform and model design:** Tailor PPP, SME, or cooperative models through feasibility and investment studies.
- **Capital structuring:** Mobilize blended finance; clarify grant, loan, and equity roles.
- **Inclusive rollout:** Pair investment with gender, training, and climate-smart capacity building.
- **Policy integration and scale-up:** Embed Artemia within aquaculture and blue economy strategies to ensure replication and long-term financing.

Why It Matters for Investors

- Across all models, **returns of 25–40 percent** and **payback periods under three years** make Artemia one of the most bankable low-trophic aquaculture ventures available.
- Each entry point offers a **different risk-return profile**—from SME-level artisanal retrofits to large-scale PPP salt-farm integrations.
- Collectively, they deliver strong **environmental, social, and governance (ESG), gender, and climate co-benefits**, aligning directly with blue economy, impact-investment, and PROBLUE objectives.

1

INTRODUCTION

Artemia, or brine shrimp, are tiny crustaceans with outsized value. Historically used as a natural feed in marine aquaculture hatcheries, Artemia plays a critical role in the early development of fish and shrimp larvae. However, its importance now spans diverse applications, from animal nutrition to human food and even biotechnology. As demand for aquaculture continues to rise, Artemia is increasingly seen not just as a niche product but as a strategic resource at the intersection of aquatic food systems, salt production, biodiversity conservation, and climate-resilient aquaculture.

This synthesis report brings together the core findings from an extensive World Bank project, '*A strategic approach to Brine Shrimp (Artemia) Aquabusiness',* that examined the global Artemia landscape. It focuses especially on the emerging frontier of Artemia aquaculture, presenting an investment-oriented perspective. While wild harvesting of Artemia still dominates global supply, this resource is stagnating, and future demand must come from more reliable, scalable, and sustainable farming systems for Artemia.

This synthesis report, designed primarily for investors, government agencies, World Bank task team leaders (TTLs), and development partners, provides an accessible entry point into the world of Artemia. It simplifies complex technical information while offering the facts and figures that matter to decision-makers: production volumes, market flows, economic potential, social impact, environmental considerations, and investment-readiness opportunities and indicators.

This report draws on key findings from in-depth studies that examined Artemia production systems, value chains, governance frameworks, global trade dynamics, and emerging innovations. These background deliverables are cited throughout and can be accessed for readers seeking further technical detail or guidance.

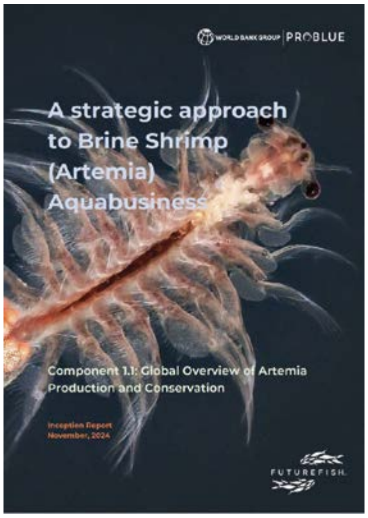
From Asia's advanced cyst production models to Africa's untapped farming potential, this synthesis shows why Artemia deserves a prominent place on the investment agenda for sustainable aquaculture and blue food systems.

2

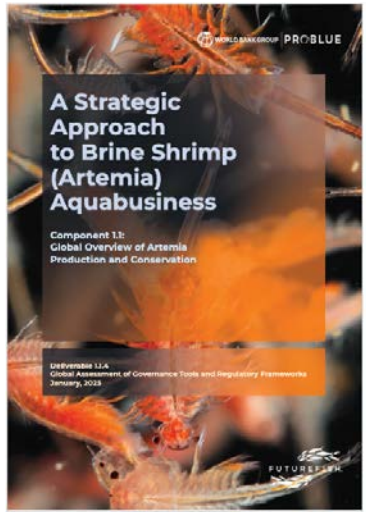
METHODS

This synthesis report is grounded in a multidisciplinary global study commissioned by the World Bank, with research conducted from November 2024 to April 2025. The work combined field assessments, stakeholder consultations, market analyses, technical reviews, and value-chain case studies across multiple Artemia-producing regions. The aim was to assess the current and future potential of Artemia production, especially farmed Artemia, and to develop guidance for scaling investment-ready models.

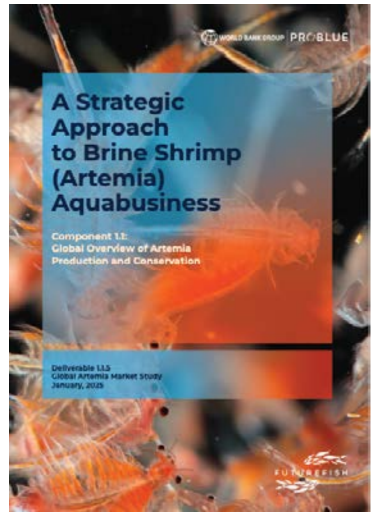
The analysis spanned several key deliverables.



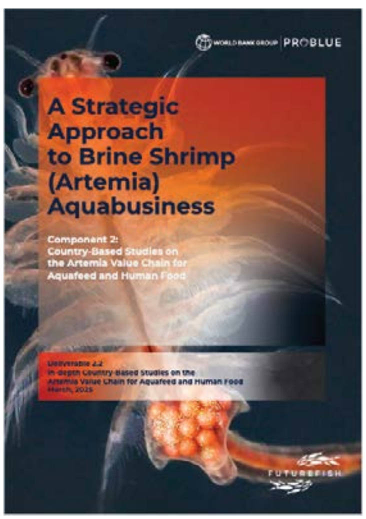
A global overview of Artemia production and conservation practices



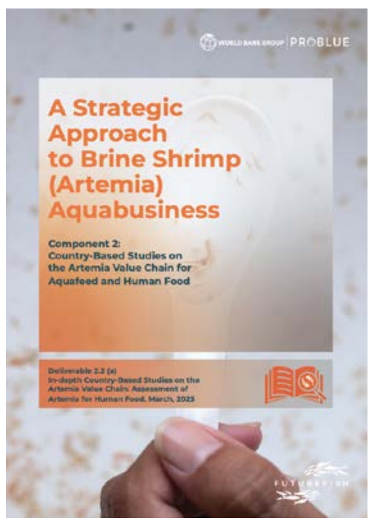
An assessment of governance frameworks and regulatory gaps



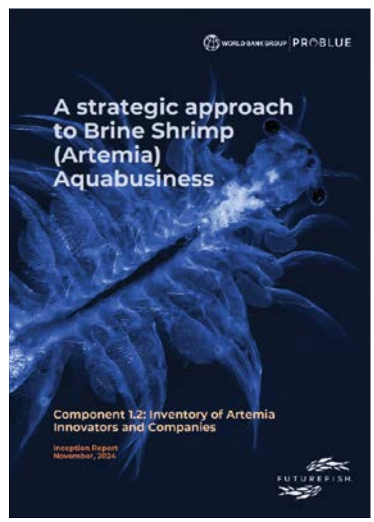
A global market study, highlighting trade flows, price dynamics, and demand forecasts



Country-specific value-chain case studies in China, Viet Nam, Thailand, Bangladesh, and Kenya



A study on the potential for Artemia in human food system



A global inventory of technologies, stakeholders, and innovations.

The methodology combined qualitative and quantitative approaches. Field teams interviewed hatchery managers, salt producers, local authorities, and community members. Market data was sourced from customs records, industry databases, and expert interviews. Environmental and social factors were reviewed alongside economic indicators to assess sustainability, scalability, and impact.

This synthesis distills the core insights from the above reports. This synthesis report acts as a decision-support tool for those seeking to understand Artemia's investment profile. Full technical documents are available upon request or on designated World Bank platforms. This report follows the same logical flow as the background research and uses consistent terminology, metrics, and case examples. Where relevant, visual tools such as maps, flowcharts, and infographics are suggested to enhance the Artemia investment profile.

By connecting technical realities with investment strategy, this synthesis equips stakeholders with the insights needed to catalyze Artemia's transformation from a niche aquaculture input to a cornerstone of sustainable blue food systems.

3

WHAT IS ARTEMIA?

Artemia, or brine shrimp, are minute crustaceans found in hypersaline environments around the world, such as natural salt lakes and manmade seawater evaporation ponds and salt pans. Their evolutionary adaptability allows them to thrive in extreme salinity levels that exclude most predators and competitors. This resilience has made them a valuable asset in aquaculture, where their inactive cysts (eggs) can be widely traded and live biomass is used as a high-quality live feed for shrimp and fish larvae.

The life cycle of Artemia includes multiple stages: cyst, nauplius (larval stage), juvenile, and adult. Cysts can remain inactive for years, making them easy to store, transport, and hatch on demand—a trait that has underpinned their global trade and use in shrimp and fish hatcheries. When hydrated in seawater and exposed to light and oxygen, cysts hatch into nauplii within 15 to 48 hours, offering a reliable live feed rich in essential fatty acids, proteins, and energy.

Artemia is uniquely suited to sustainable aquaculture farming. Their diet consists of microalgae, detritus, and particulate organic matter, and they can be reared with minimal technological inputs in salt-rich environments. This allows Artemia farming to align well with salt production, wastewater reuse, and other low-input, circular economy models.

Beyond aquaculture, Artemia's biological traits have attracted attention from other sectors. In biotechnology, Artemia has been used as a model organism for toxicological studies and biomedical research, including cancer treatment trials. Artemia cysts have also been deployed in space biology experiments aboard NASA and Roscosmos missions to study life in microgravity and extreme environments. In natural ecosystems like salt lakes, Artemia provides a primary food source for migratory birds such as flamingoes, sustaining entire food webs. Artemia also has growing roles in other industries. In research and biotechnology, Artemia is used as a model organism in ecotoxicology, pharmaceutical screening, and biomedical studies due to its fast reproduction, small size, and sensitivity to pollutants and drugs. Artemia's use in toxicity testing, particularly in assessing new compounds for human use, is widespread due to its ethical acceptability and low cost.

This combination of adaptability, storability, and ecological function makes Artemia a key and resilient biological asset with expanding value. As markets and farming systems evolve and diversify, Artemia's utility is growing well beyond its origins as a marine hatchery input for high-value marine species, laying the foundation for scalable, sustainable, and innovative production systems across geographies and sectors.

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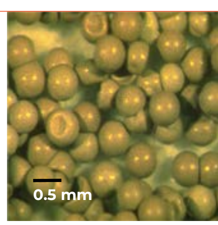
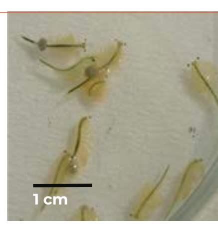
WHAT IS IT USED FOR?

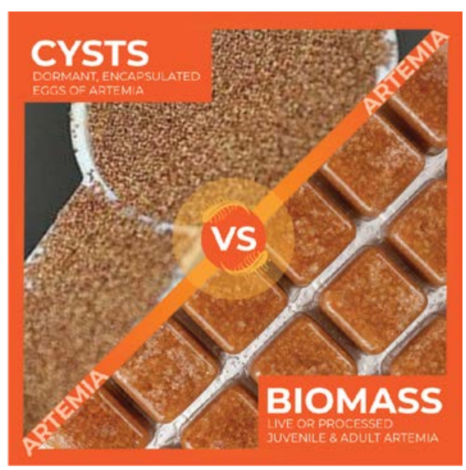
Artemia is widely recognized as a cornerstone input in aquaculture, but its applications extend well beyond that. Its most well-known use is as live feed in fish and shrimp hatcheries, where Artemia nauplii are prized for their high nutritional content, digestibility, and ease of use. Hatcheries rely on Artemia as a transitional feed for larvae until they can consume formulated feed, particularly for high-value species such as shrimp, crabs, marine finfish, and ornamental species.

Artemia Cysts



Artemia Biomass





Artemia cyst the dormant, encapsulated embryo stage. When dehydrated, cysts can remain viable for years, making them a highly portable and storable product. Once rehydrated in seawater, they develop into nauplii within 15–48 hours, providing a critical live feed for shrimp and fish hatcheries. Due to their hatchability, storability, and high protein and lipid content, Artemia cysts are in high demand across global aquaculture. Wild-harvested cysts can command prices of USD 30 to over USD 100 per kilogram, depending on origin, moisture content, hatch-out rate, size, and nutritional value, while some farmed cysts can reach prices of more than USD 200 per kilogram.

Cyst production is typically seasonal, aligned with warm weather and optimal salinity conditions. Harvesting involves filtering brine, collecting cysts, either from the lake's surface or from the shoreline, drying them, and packaging them in oxygen-free, vacuum-sealed tins or foil bags. Farmed cysts offer enhanced quality control compared to wild-sourced counterparts and allow for innovations such as biofortification—where cysts are enriched with essential fatty acids or micronutrients to boost hatchery performance.

Artemia biomass, on the other hand, refers to the live or processed juvenile and adult Artemia. It can be sold fresh, frozen, or dried and is commonly used in the ornamental fish industry, as nursery and grow-out feed for shrimp, in shrimp broodstock feed, for larval feed in non-shrimp species, or increasingly in experimental feed formulations for poultry, livestock, and aquaculture species. Artemia biomass is highly nutritious, with protein levels comparable to fish meal, along with a favorable amino acid and fatty acid profile and high digestibility. In addition, it can be grown continuously in suitable climates, offering more frequent harvesting opportunities than cyst production.

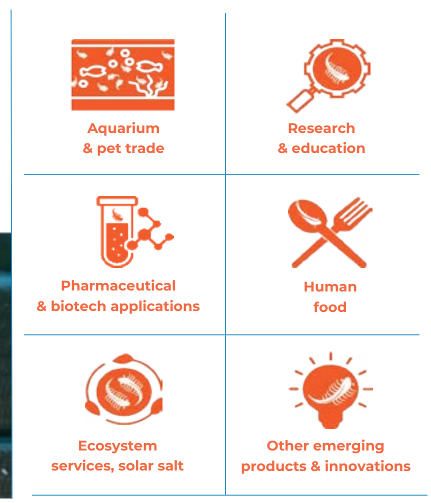
While cysts have historically dominated global trade, interest in biomass is growing due to its potential as a low-cost, local live feed alternative and its suitability for diversification into human food or animal feed-grade applications. The development of value-added products, such as processed Artemia cakes, powders, or pellet ingredients, could further unlock commercial potential, especially in regions with animal protein constraints.

Understanding the distinctions between cysts and biomass—and investing in flexible production systems that can pivot between them—is key to building resilient Artemia farming enterprises. Both forms offer commercial value, and when managed effectively, can support diversified markets and year-round revenue generation.

Aquaculture

Artemia is valued as a highly nutritious feed for early stage shrimp and fish production, supporting >10 million tonnes of aquaculture production

Feast time!
A giant tiger prawn devours free-swimming adult Artemia (see white dots)



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ECONOMIC IMPORTANCE

Artemia underpins a global industry valued at over USD 400 million annually, driven largely by its central role in aquaculture hatcheries. The global aquaculture sector continues to expand rapidly—particularly shrimp farming, which reached nearly 5 million tonnes in 2022—fueling rising demand for high-quality, reliable larval feed. Artemia remains a critical and irreplaceable component of this equation, valued for its hatchability, ease of storage, and exceptional nutritional profile.

The cyst market alone is estimated at approximately USD 200 million, with wholesale prices ranging from USD 30 to over USD 100 per kilogram depending on quality, origin, and certification. Top exporters such as the United States, Russia, and China dominate global cyst trade, while key importers include Ecuador, China, India, Thailand, Indonesia, and Viet Nam—countries with large hatchery-based aquaculture industries.

In addition to its contribution to hatchery efficiency and survival rates, experiences with Artemia farming in Asia indicate its potential to become a source of local economic transformation. Countries that develop local Artemia value chains—especially in saline or semi-arid zones—can tap into a growing market while diversifying incomes for salt farmers, artisanal aquaculture producers, and women’s cooperatives. Farmed Artemia also offers scope for enhancing biosecurity and improving hatchery outcomes.

As new applications in human food, biotechnology, and animal nutrition continue to emerge, the value of Artemia is poised to grow further. A farm producing just 5 tonnes of Artemia cysts annually can generate revenues exceeding USD 250,000, depending on quality and market conditions. Similarly, biomass production—currently underexploited—has shown promising returns in pilot operations when sold as animal feed or processed for nutraceuticals.

BREAKDOWN OF ARTEMIA PRODUCTION (MT) INTO SHRIMP PRODUCTION (MT)

Shrimp farming is growing and artemia production will need to diversify

1. **Artemia Cyst Requirement for Shrimp PL Production**
    - 2.5 kg of Artemia cysts are needed to produce 1 million post-larvae.
2. **Survival Rate to Harvest**
    - 50% of post-larvae survive to reach harvest size (20 g per shrimp).
    - This means 1 million post-larvae ➔ 500,000 shrimp at harvest size.
3. **Shrimp Biomass Calculation**
    - 500,000 shrimp at 20 g each result in 10 metric tonnes (MT) of shrimp.
    - So, 2.5 kg of Artemia cysts produce 10 MT of shrimp.
    - This means 250 g of Artemia cysts are needed per 1 MT of shrimp.
4. **Artemia Naupliar Biomass Calculation**
    - 1 g of Artemia cysts hatch into 220,000 nauplii.
    - Each nauplius has a dry weight of 2 µg.
    - Thus, 1 g of cysts produces 440 mg of naupliar dry biomass.
    - 250 g of cysts would then produce 110 g of naupliar dry biomass.
    - This 110 g of Artemia nauplii supports the production of 1 MT of shrimp.

Summary

- **250 g of Artemia cysts** are required to produce **1 MT of shrimp** (assuming a 50% survival rate from post-larvae to harvest).
- **110 g of Artemia nauplii dry biomass** contributes to producing **1 MT of shrimp**.
- In theory, if 80% of all artemia is used for shrimp production, then roughly 2,800 MT of artemia could produce 11.2 million tonnes of shrimp (current production is at just under 6 million tonnes, indicating the large differences in hatchability between cyst types and shrimp survival during pond production).

The economic potential is particularly promising in countries with abundant solar salt ponds, coastal wetlands, or saline-affected inland lands. Low-cost integration with salt production further reduces capital and operational expenditures, offering competitive returns on investment (ROIs). Artemia also allows for productive reuse of otherwise marginal or degraded landscapes, turning low-value assets into income-generating biological systems.

In summary, Artemia represents both a high-margin input in the aquaculture industry and a platform for broader rural development. Its combination of biological value and economic scalability makes it a compelling target for strategic investment, particularly in countries looking to strengthen aquatic food systems, improve rural livelihoods, and build resilience in saline environments.

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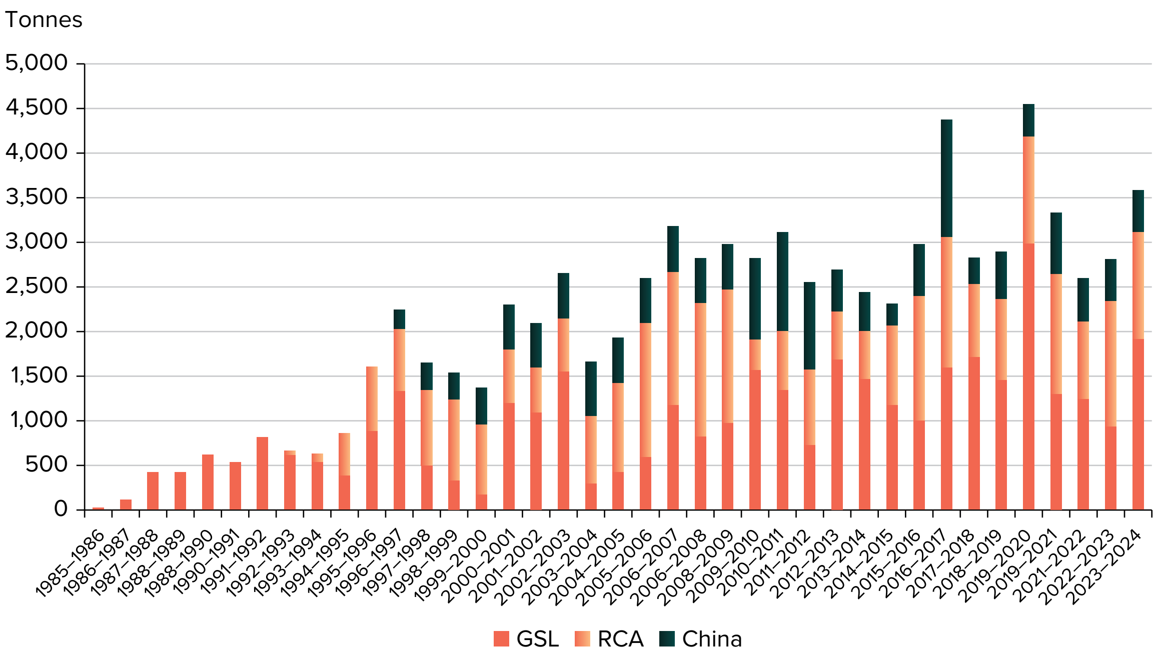
WILD HARVESTING: A STAGNATING RESOURCE

Wild Artemia harvests have historically underpinned global aquaculture, supplying roughly 90 percent of the cysts used in shrimp, marine fish, and crab hatcheries. Key sources include hypersaline lakes in the United States (Great Salt Lake, GSL), China (Bohai Bay), Russia, and Central Asia. While these stocks remain essential, their capacity to meet growing global demand is increasingly constrained.

Declining GSL harvests in the mid-1990s, driven by water-level fluctuations and environmental pressures, exposed the risks of relying on a single dominant source. To address this, the Artemia Task Force (ATF-IAQ) was established in 1995 to identify alternative sources, prompting significant harvesting in China, Russia, and Central Asia (Lavens and Sorgeloos 2000). By the late 1990s, these regions were contributing substantial volumes to the global market. Chinese Artemia, initially for domestic use, began exporting widely by the 2000s, alongside supplies from Kazakhstan. Over the past five years, the total global supply reached nearly 3,500 MT annually, up from a 20-year average of 2,600 tonnes.

Aral sea from 1987 to 2023 going from freshwater of 35 g of salt per litre (g/l) to 200 g/l by 2023

Global artemia harvest from 1895 to 2024



Despite this diversification, environmental and ecological pressures continue to constrain wild Artemia. The GSL faces dramatic water-level drops from upstream diversions and climate change, reducing cyst yields and stressing the ecosystem. Other wild sources are affected by inconsistent harvests, variable cyst quality, and operational challenges, including limited infrastructure, political instability, and complex trade logistics. Hatchery integration also varies by species: GSL *Artemia franciscana* naturally breaks diapause, whereas parthenogenetic Artemia from Russian and Kazakh lakes require hatching enhancers, developed by INVE Aquaculture, to ensure reliable production.

Regulatory frameworks further complicate reliance on wild stocks. Quotas, licensing schemes, and conservation measures safeguard biodiversity but introduce uncertainty for hatcheries needing consistent supply. Variability in hatchability, purity, and moisture content limits suitability for specialized aquaculture applications. The International Artemia Aquaculture Consortium (IAAC) desires to develop standardized cyst certification—including QR codes—to enhance traceability and inform buyers about product characteristics.

Economically, wild Artemia remains exposed to price volatility. Annual yields fluctuate with environmental conditions, affecting cost predictability for hatcheries and feed producers. With ecological, regulatory, and operational ceilings, wild harvests alone cannot support projected growth in global aquaculture—particularly in shrimp and marine fish sectors across Asia, Latin America, and Africa.

This scenario underscores the need for diversification and creates a clear opportunity for Artemia farming. Semi-intensive, intensive, and integrated production systems—spanning solar saltworks, artisanal ponds, dedicated ponds, and tank systems—can deliver high-quality, consistent cysts and biomass at scale. Farming leverages regional advantages, including climate, brine-rich resources, and existing salt infrastructure, while aligning with production economics and market demand. Successful examples from China, Viet Nam, India, Uzbekistan, and parts of Africa demonstrate that farmed Artemia can reliably meet hatchery needs, generate income for local communities, and strengthen food security.

By combining technical feasibility with robust business analysis, Artemia farming can transition from a niche supplement to a strategic, market-aligned solution. Farmed production reduces pressure on fragile ecosystems, secures reliable supply for global aquaculture, and creates a scalable, sustainable pathway to meet future demand.

7

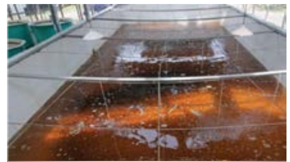
ARTEMIA FARMING AS THE NEW FRONTIER

Today, global Artemia cyst production stands at around 3,500 tonnes annually, with over 40 percent sourced from the GSL alone. Projections based on current uses in marine hatcheries suggest demand could rise to over 5,000 tonnes by 2035—an increase equivalent to the output of another GSL, which does not currently exist. Climate change and environmental stressors are diminishing the reliability of wild sources, reinforcing that future growth must come from farmed production.

The global Artemia aquabusiness is entering a new chapter driven by aquaculture. Less than 10 percent of Artemia cysts are currently farmed, and only a few hundred farmers worldwide are engaged in this activity. Emerging farming technologies—especially when integrated with solar salt production—provide a scalable, resilient, and environmentally sound production pathway.

Farmed Artemia systems range in complexity and design. At the most basic level, Artemia can be reared in earthen ponds adjacent to salt pans, using nutrient-rich brine and natural sunlight to stimulate algal growth, which serves as Artemia's primary feed. More advanced systems include lined raceways, modular tanks, and controlled hatchery environments that support year-round production. These approaches can produce both cysts and biomass, depending on market requirements. Further innovation can increase efficiencies in production systems, while scaling can occur rapidly using existing technological knowledge.

Three farming models gaining traction:

ARTEMIA FARMING MODELS: Three farming models gaining traction:	 **Integrated Salt-Artemia Systems**	 **Cyst-Focused Farming**	 **Biomass-Focused Systems**
	Found in China, Bangladesh, and parts of Africa (Kenya and trialed in Mozambique, Madagascar, Tunisia)	As seen in Viet Nam	Found in Thailand's coastal farms
	Repurposes brine from salt production for Artemia cultivation; promotes circular use of resources.	Optimized for cyst yield through controlled salinity and strategic harvesting.	Produces live or processed Artemia biomass for markets like ornamental fish, and aquatic animal feed.

Farmed Artemia offers several clear advantages. First, it allows for traceability and biosecurity, with scope for managing the risk of contamination. Second, it enables product customization—such as selected species or strains, and biofortified cysts with added nutrients for enhanced hatchery performance. Third, farming allows year-round production in controlled settings, smoothing seasonal and geographic supply gaps.

Economically, farming Artemia aligns well with circular production models. Farms in China, Thailand, and Viet Nam use local labor, recycled water, and shared infrastructure with salt producers, lowering input costs. Moreover, farming can be scaled incrementally, with pilot systems requiring modest start-up capital but offering attractive returns when optimal productivity is achieved. The technologies are proven, scalable, and low cost—making this a timely and strategic opportunity for investors.

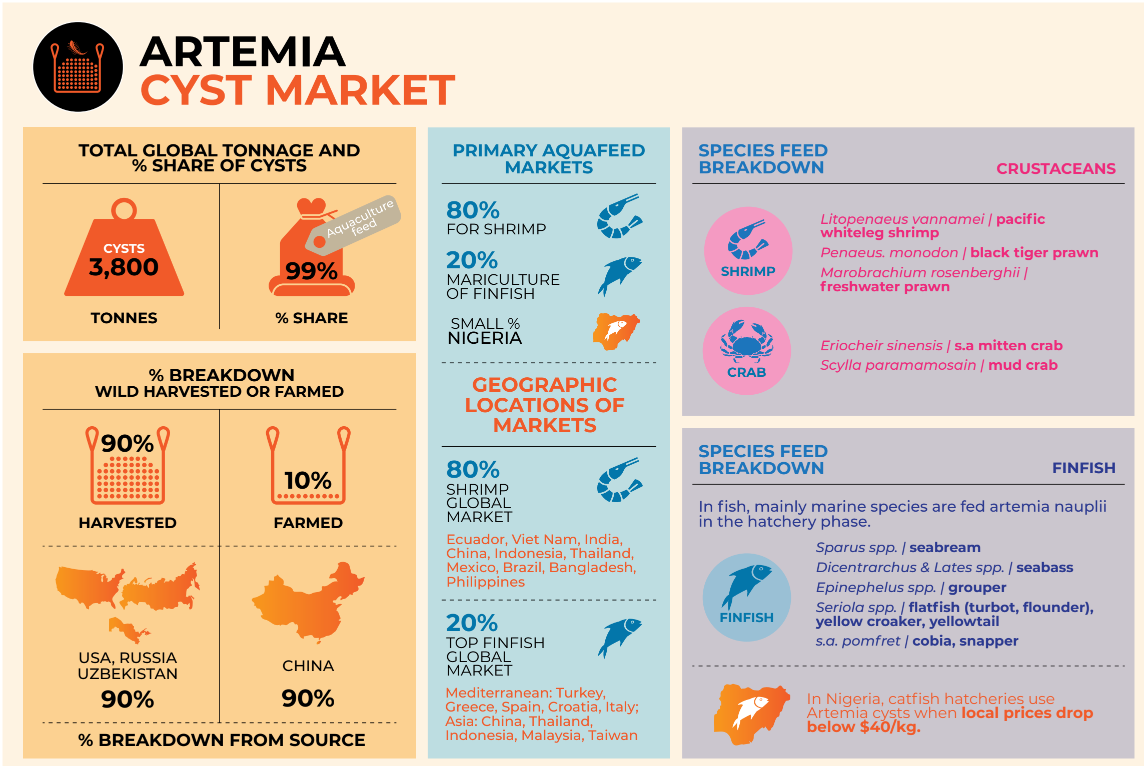
8

GLOBAL SUPPLY AND DEMAND

The global Artemia market is dynamic, evolving alongside the expansion of aquaculture and emerging interest in alternative protein sources. Presently, total global production of Artemia cysts is estimated at approximately 3,800 MT per year, the majority of which is derived from wild harvesting in regions like the United States (primarily the GSL), Russia, Kazakhstan, and China. The GSL alone accounts for over 40 percent of the global supply.

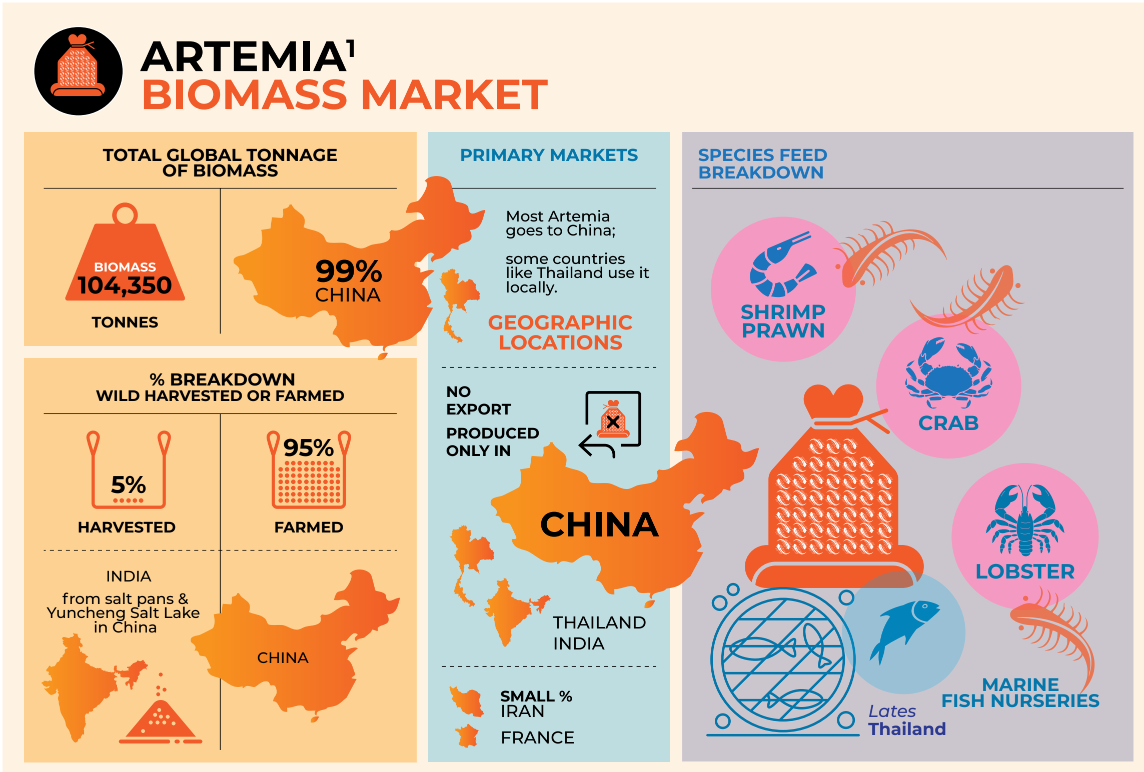
Demand for Artemia cysts is growing steadily, especially in shrimp-producing countries such as India, Indonesia, Thailand, Viet Nam, and Ecuador. These nations have large hatchery industries that rely on high-quality, dependable sources of Artemia nauplii for larval survival and growth. Projections based on marine aquaculture expansion suggest that global demand could reach over 5,000 tonnes annually by 2035, reflecting broader growth trends in aquaculture, especially for more species or crustaceans and marine fish and increasing interest in traceable, high-performance live feeds.

Trade data shows strong import demand from countries with large shrimp hatchery sectors and limited domestic production. India and Ecuador are top importers, followed by China, Viet Nam, Thailand, and Indonesia. Meanwhile, the United States and Russia remain dominant cyst exporters, with China and Viet Nam rising as farmed cyst producers. Pricing trends indicate steady appreciation, particularly for certified and biofortified cysts, which can fetch premium prices on the global market.



Biomass, while less formally tracked, is seeing increasing regional demand. China, Thailand, and Bangladesh are piloting or scaling up Artemia biomass production for local feed markets, particularly in ornamental fish, integrated aquaculture, and even livestock systems.

As the aquaculture industry continues to scale, the Artemia supply chain will need to transition toward more sustainable and controlled production systems. The growing demand for quality, biosecure, traceability, and environmental safeguards aligns strongly with the capabilities of farmed Artemia—making it a high-priority segment for strategic investment and policy support.

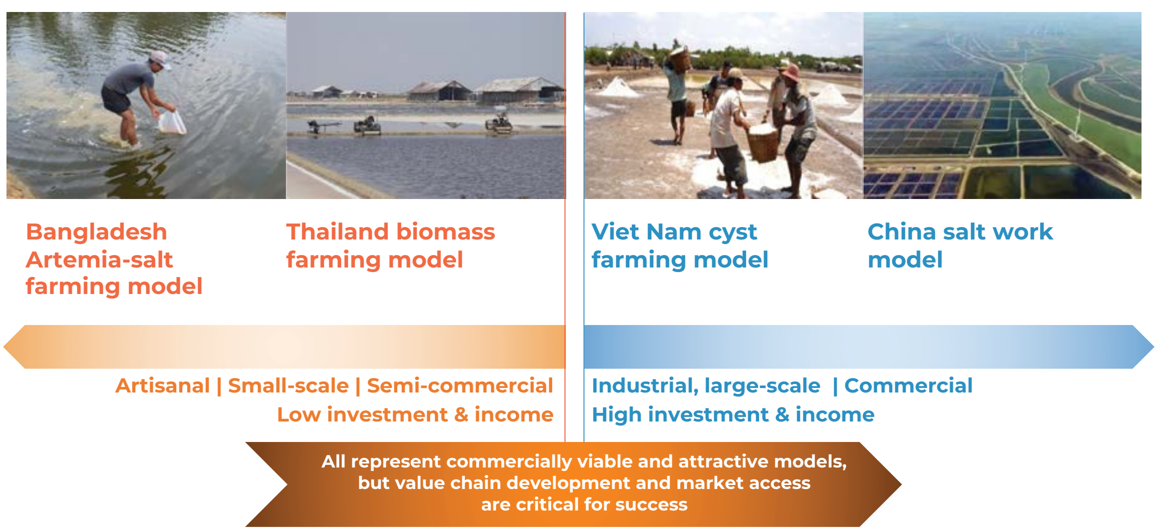


1 This map is for illustrative purposes and does not imply the expression of any opinion on the part of the World Bank concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries.

9

COUNTRY CASE STUDIES

Five value chain case studies were conducted to more broadly inform future investment strategy, covering the following:



Brief descriptions of each country's case study and learning are provided below, with key characteristics of each model provided in Annex A.

China - Solar Salt Works

China has emerged as one of the most important producers of Artemia globally, leveraging its vast network of solar salt ponds in coastal provinces, particularly Shandong, Jiangsu, and Hebei. These saline landscapes offer an ideal environment for Artemia cultivation, providing stable salinity, consistent brine replenishment, and the infrastructure necessary for cost-effective biomass and cyst production.

China's Artemia farming model is characterized by its integration with traditional salt production systems. Artemia are cultured in intermediate and final crystallization ponds during non-peak salt harvesting months. These systems benefit from low overhead costs since land, water, and labor are already structured for saltworks, and only minor adjustments are required to transition toward Artemia production. As a result, production costs are lower than in many other countries, and the systems have been adopted by both state-run and private operators.

The Artemia chain in China is relatively well-organized. Hatcheries and processing plants are typically located near production zones, reducing post-harvest losses and enabling efficient quality control. Standardization and grading systems are in place, although further improvements in certification and traceability could enhance competitiveness in premium markets. Some producers are experimenting with enrichment technologies and improved harvesting techniques to boost hatch-out rates and expand into biofortified markets. Challenges in the Chinese Artemia sector include rising environmental pressures in coastal regions, land-use competition from real estate and aquaculture expansion, and increased scrutiny over brine discharge and water quality management. Nonetheless, the country's combination of infrastructure, experience, and scale offers significant opportunities for continued growth and modernization.

China's model demonstrates the viability of Artemia farming within existing salt systems, serving as a blueprint for other nations with similar saline environments. The country's continued investment in infrastructure and quality control positions it as a cornerstone of the global Artemia trade—and a clear example of how integration and scale can drive production efficiency and profitability.

CHINA[2] Artemia Solar Saltworks

ARTEMIA COUNTRY PROFILE

PRODUCTION SYSTEM

Salt Solar Works

High Productivity & Stable Production:

CYSTS 500 600 TONNES ANNUALLY [wet weight]

BIOMASS 1000 TONNES ANNUALLY

MARKETS

1000 1500

High Demand & Usage: China needs **1000-1500 tonnes of cysts/yr**

99%

Biomass - 99% of **global production:** used domestically for shrimp farms, ornamental fish feed

Shortfall: imports 800-1000 tonnes of cysts

ADVANTAGES

Stable salinity and brine supply ideal for Artemia cultivation

Low production costs compared to other countries

Adopted by both state-run and private operators

Efficient value chain

CHALLENGES

Environmental pressures in coastal areas

Land-use conflicts with real estate and expanding aquaculture

Growing regulatory scrutiny over brine discharge and water quality.

SOCIO-ECONOMIC IMPACTS

1000

Creates 1000 jobs

Improves salt quality by reducing brine viscosity

BUSINESS MODEL Cysts Biomass Large Solar Saltworks

CYCLE TIME	TONNES PER HA / PER CYCLE	COST PER KG	SELLING PRICE PER KG	REVENUE PER HA	PROFIT MARGIN
APRIL to NOVEMBER	Cysts: Produced in large salt ponds (30-60 ha per pond); Biomass: High-yield, large-scale collection	$0.30 KG BIOMASS	$150% HIGHER THAN INLAND CYSTS; PREMIUM CYSTS $100 KG; LIVE BIOMASS $1-2 KG	$6000 - $30,000 per year	30-50% Stable due to high demand; cysts sold at a premium due to better hatchability and nutrition

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Viet Nam - Premium Cyst Farming

Viet Nam has positioned itself as a leader in the production of high-quality, farmed Artemia cysts, particularly in the Mekong Delta region. With no access to wild Artemia resources, the country has invested in domesticated Artemia strains and refined farming techniques to achieve consistent, premium-grade output for both domestic and international markets.

Artemia farming in Viet Nam is predominantly small- to medium-scale and integrated with shrimp hatcheries or salt production areas in provinces such as Bac Lieu, Soc Trang, and Ca Mau. Farmers operate saline ponds where they cultivate Artemia in controlled salinity conditions, with cysts harvested seasonally and dried on-site or in nearby processing facilities. Small cyst size, high nutritional value, and excellent hatch-out rates make Vietnamese farmed Artemia attractive to hatcheries that prioritize quality and reliability, for example as starter food for mud crab and selected marine fish species.

What distinguishes Viet Nam's model is its emphasis on product quality and the strength of farming cooperatives. National aquaculture research institutions have played a central role in disseminating best practices, improving Artemia strains, and supporting farmer cooperatives. This has enabled the country to position itself as a premium supplier, especially in niche or traceability-sensitive markets.

Despite its strengths, Viet Nam's Artemia sector faces challenges, including salinity fluctuations due to rainfall, competition for pond space with shrimp farming, and the need for consistent water quality management. Nonetheless, the sector's alignment with the country's broader aquaculture goals—particularly shrimp export growth and farming of new species—creates strong incentives for continued development and innovation. Viet Nam demonstrates that with focused investment in quality, traceability, and farmer training, small-scale Artemia farming can be transformed into a premium, export-oriented value chain. Its success offers lessons for other countries seeking to differentiate themselves through farmed Artemia production.

VIET NAM[3] Premium Cysts Farming

ARTEMIA COUNTRY PROFILE

PRODUCTION SYSTEM

Premium Cysts Farming

Cultivated in monoculture & integrated systems (with salt, shrimp, crab, etc.)

CYSTS 20 30 TONNES ANNUALLY [dry weight]

~ $4 - 6 million

ADVANTAGES

Robust farmer cooperatives supported by National aquaculture research institutions.

Well-aligned with Viet Nam's aquaculture strategy

CHALLENGES

Salinity fluctuations

Pond space competition with shrimp farming

Ongoing need for water quality management.

MARKETS

Market niche: Exceptional quality, high PUFAs and hatchability

Local demand: **80% domestic** but can be **exported over $200/kg**

Shortfall: still imports 500 tonnes of cysts

SOCIO-ECONOMIC IMPACTS

2-3 workers per hectare **20% women**

2000

Creates 2000 jobs

BUSINESS MODEL Artemia Cysts Salt Pond Farming

CYCLE TIME	TONNES PER HA / PER CYCLE	COST PER KG	SELLING PRICE PER KG	REVENUE PER HA	PROFIT MARGIN
4-5 Months	Cysts: 50-70kg/ha 150-200kg in intensive systems; Biomass: 4-5m tonnes	$15-20KG; BIOMASS	HIGH-QUALITY Viet Nam CYSTS: CYSTS $200 KG; BIOMASS $50-100KG	Cysts: $10,000 per hectare, per season; Biomass: Additional Revenue Stream	30-50% For farmers but processors take a further 60%, meaning **total margin is over 90%**

3 This map is for illustrative purposes and does not imply the expression of any opinion on the part of the World Bank concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries.

Thailand - Biomass Farming

Thailand is pioneering the development of Artemia biomass farming, shifting the traditional focus from cysts to the live and processed forms of adult Artemia. This model supports the country's ornamental and aquaculture sector, which requires steady supplies of live feed, and opens the door for novel feed ingredient applications in other aquaculture species, poultry, and even pet food.

Biomass production in Thailand is primarily located in coastal saline zones, either integrated within salt-producing regions of the Gulf of Thailand or ex-shrimp ponds. These farms use tailored saline water and local brine sources to raise Artemia in nutrient-rich environments. Harvesting is typically done through net collection, and the biomass is either sold fresh, chilled, or dried, depending on market demand.

Thailand currently produces an estimated 250 tonnes of Artemia biomass annually, with a growing share directed toward domestic feed formulations. This model allows for multiple harvests per year and avoids the seasonality associated with cyst production. Because it does not require drying, packaging, or international logistics, biomass farming can serve local and regional markets efficiently.

One of Thailand's key innovations lies in its integration of Artemia biomass into value-added feed products. Several feed companies and aquaculture firms are developing pilot feed blends that include Artemia meal or paste as a digestible, high-protein supplement. These feeds are showing promising results in larval growth and survival trials for species like catfish, tilapia, and ornamental fish.

Challenges remain in terms of standardizing biomass quality, ensuring year-round salinity control, and developing consistent market channels. However, the scalability and relative simplicity of biomass production make it well-suited for small and medium enterprise (SME) adoption and vertical integration with existing aquaculture value chains.

Thailand's experience highlights the viability of biomass-focused Artemia farming, particularly for countries with limited access to coastal saline areas. It also illustrates how Artemia can evolve beyond its cyst-centric value chain to become a flexible, multi-product resource for diversified feed markets.

THAILAND[4] Biomass Farming

ARTEMIA COUNTRY PROFILE

PRODUCTION SYSTEM

Biomass Farming

Located in coastal saline zones

Over 20 intensive and semi-intensive ponds

250T PER YEAR

Produces around 250 tonnes of biomass per year.

ADVANTAGES

Year-Round Supply: Multiple harvests avoid cyst seasonality.

Local Integration: Uses saline zones and ex-shrimp ponds efficiently.

Low Logistics Costs: Sold fresh/chilled/dried—no drying or export needed.

Well suited for SME adoption and vertical integration with existing aquaculture value chains.

MARKETS

Export opportunity: **25% of biomass** processed and **exported**

Specialised market: biomass

Supply shortfall: 110 tonnes of biomass

Reliance on imported cysts: 650 tonnes

CHALLENGES

Standardizing biomass quality

Ensuring year-round salinity control, and developing consistent market channels

SOCIO-ECONOMIC IMPACTS

Decreased dependence on imports but still limited jobs

BUSINESS MODEL Artemia Biomass Pond Farming

CYCLE TIME	TONNES PER HA / PER CYCLE	COST PER KG	SELLING PRICE PER KG	REVENUE PER HA	PROFIT MARGIN
Year-round Operation	Biomass 2-4 tonnes	\$0.15-0.50KG (BIOMASS)	CYSTS \$1.75-1.78KG; BIOMASS \$1.50-1.63KG	Up to \$38,000 per farm, per year	50-90% Profit until end-user can be 50-90%, with processors taking 30-40%

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Bangladesh - Integrated Salt and Artemia Farming

Bangladesh represents a compelling case for integrated Artemia and salt farming in low-income, coastal environments. In the country's southern saline districts, particularly in Cox's Bazar and Satkhira, saline-affected land is abundant but often underutilized. Through donor-supported pilots and public-private initiatives, Bangladesh is now exploring how Artemia can be integrated into existing salt pans and aquaculture ponds to generate additional income streams for smallholder and artisanal producers.

The Bangladesh model is based on seasonal polyculture, where Artemia is cultivated alongside or in rotation with salt and fish species such as tilapia or mullet. The brine used for salt crystallization is diverted into Artemia ponds during the off-season or interspersed between salt harvesting cycles. This efficient reuse of saline water enhances land productivity while minimizing capital investment.

One of the standout features of the Bangladesh model is its strong alignment with social inclusion goals. Artemia farming has been promoted among women's groups and community-based cooperatives, offering a new source of livelihood in saline and climate-vulnerable zones. These systems also support climate adaptation, turning marginal saline lands into productive assets that buffer against the economic shocks of erratic rainfall and rising sea levels.

However, challenges remain. Artemia farming is still largely unfamiliar to most producers, and technical capacity is limited. Salinity control, cyst processing, and market links all require strengthening. Ongoing training and institutional support—backed by the government and business investment—will be essential for scaling.

BANGLADESH[5] Integrated Salt & Artemia Farming

ARTEMIA COUNTRY PROFILE

ADVANTAGES

Driven by donor-supported pilots and public-private partnerships

Aligns with national goals for social inclusion and climate-smart agriculture.

CHALLENGES

Low awareness and technical capacity

Requires training, extension services, and investment to mature the value chain.

Salinity control, cyst processing, and market linkages required strengthening

PRODUCTION SYSTEM

Integrated Salt & Artemia Farming

Seasonal polyculture integrating Artemia with Salt production or other fish species

54 integrated salt-artemia-tilapia farmers (5 ha)

BIOMASS	CYSTS	TILAPIA
6.7T	8KG	35MT
1.6MT/ha		

MARKETS

Year-round income through integrated Artemia and salt farming (dry season) and tilapia production (rainy season)

High price: biomass sold as high as **$5/kg** and local cysts sold cheaper than imports

$5KG

Shortfall: 50 tonnes of cysts

SOCIO-ECONOMIC IMPACTS

Employed 144 seasonal workers

+$1,300

Additional $1,300 per farmer / year

BUSINESS MODEL Year-round Integrated Artemia Salt Farm

CYCLE TIME	TONNES PER HA / PER CYCLE	COST PER KG	SELLING PRICE PER KG	REVENUE PER HA	PROFIT MARGIN
January - May or Year-round	Cysts ~17 kg/ha; Biomass 1.3-1.4 tonnes	CYSTS $36 KG; BIOMASS $1.4 KG	CYSTS $50-100KG; BIOMASS $4.0-5.0KG	$8,000 est. per season per ha	40-50% But variable and dependent on local demand and production efficiency

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Kenya - Taking Artemia Farming to Africa

Kenya is one of the first African countries to invest in Artemia farming as a strategic opportunity for blue economy development. The country's efforts are concentrated around integrating solar salt farming with Artemia pond production.

Kenya is at the early stages of development, with a handful of pilot projects supported by government research institutions and development partner grants. These pilots have demonstrated that Artemia can be cultivated successfully in Kenya's saline ponds. The experience shows the importance of market development; the focus has primarily been on biomass production for local feed applications, though interest in cyst production is growing.

Kenya's value proposition lies in its combination of natural hypersaline resources, year-round sunshine, and growing demand for affordable, local sources of live feed for tilapia and catfish hatcheries. Artemia farming could fill a critical gap in the country's aquaculture sector, which often relies on costly imported feeds and inputs. Additionally, biomass farming aligns with the government's ambition for the employment of smallholders and youth in the country's coastal and inland saline regions.

Initial production figures from trials suggest potential annual biomass yields of 20–30 tonnes per site under semi-intensive systems, with room for significant scaling. However, challenges remain, including market development, technical expertise, limited hatchery infrastructure, and inadequate policy frameworks to support Artemia investment. Ongoing support is needed to develop extension services, build capacity among farmers, and connect producers to downstream markets.

Importantly, Artemia farming in Kenya also offers environmental benefits. Many of the target zones are degraded or saline-affected landscapes with limited agricultural potential. Repurposing these areas for Artemia aligns with land restoration and climate resilience goals and can create alternative livelihood options in dryland economies. Kenya's early-stage efforts show how Artemia farming can be adapted to African contexts with the right markets, technical support, and policy incentives. With strong foundational work already underway, the country could become a continental pioneer—showcasing Artemia as a viable climate-smart aquaculture innovation for Africa's saline zones.

KENYA[6] Artemia Cysts & Biomass Farming

ARTEMIA COUNTRY PROFILE

ADVANTAGES

Aligns with Kenya's blue economy and climate-smart agriculture goals

Backed by pilots from government and development partner grants

CHALLENGES

Limited infrastructure, and inadequate policy frameworks to support Artemia investment.

Need for technical expertise, extension services, capacity building, and market development and linkages.

BUSINESS MODEL Integrated Salt-Artemia Aquaculture production, combining salt production and in some cases fish farming for added income

PRODUCTION SYSTEM

Artemia Cysts & Biomass Farming

Solar salt farming integrated with Artemia pond production.

Community-led artemia farmers with 85 ponds

BIOMASS 250KG

CYSTS 33KG

$3,000

MARKETS

No captive market

Untapped Potential: Kenya Artemia Cysts an biomass farming, associated with market development

High import price: Over $300/kg for cysts vs $55/kg for local cysts

Shortfall: est. 200 tonnes of cysts (in next 10 years)

SOCIO-ECONOMIC IMPACTS

Salt farming area with 350 participants, and >2,000 indirect beneficiaries (70% women & children)

40% Women

Women in the Workforce
Involved in pond construction and pond management

CYCLE TIME	TONNES PER HA / PER CYCLE	COST PER KG	SELLING PRICE PER KG	REVENUE PER HA	PROFIT MARGIN
9 Months per Year October - June	Cysts: ~ min 3kg/ha/month 33kg/ha season Biomass: ~ min 3.8kg/ha/month 250kg/ha season	CYSTS $7.0 KG BIOMASS $2.0 KG	CYSTS $62.5 KG BIOMASS $4-6 KG	Cysts: $1,700 per hectare, per season Biomass: $590 per hectare, per season	56-89% Margin on cysts around 89% and 56% for biomass

6 This map is for illustrative purposes and does not imply the expression of any opinion on the part of the World Bank concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries.

10

EMERGING APPLICATIONS - ANIMAL FEED

While Artemia is best known as a live feed for marine aquaculture hatcheries, its biomass also holds significant promise as an ingredient for the animal feed industry. Artemia biomass—harvested fresh, dried, or processed—contains 50–60 percent protein and a favorable profile of essential amino acids and omega-3 fatty acids. This makes it a high-quality, digestible alternative to fish meal, soy, and other terrestrial proteins, especially for juvenile poultry, pigs, and fish.

The global aquatic feed market was valued at USD 28.72 billion in 2022 and is projected to grow to USD 40 billion by 2032. The global livestock feed market is even greater. As pressure increases on traditional feed inputs, Artemia presents a potential new sustainable ingredient with nutritional and circular economy benefits. Thailand and Viet Nam have already begun piloting Artemia biomass in animal diets, particularly in poultry and ornamental fish. Trials show comparable or improved growth rates and feed conversion ratios, with benefits in immunity and pigmentation.

FUTURE APPLICATION OF ARTEMIA

Aquaculture Feed

- Artemia cysts and biomass will continue to be essential for fish and shrimp hatcheries.
- Sustainable production will reduce pressure on overharvested wild sources.
- Farming will allow the use of improved breeds that can not be found in the wild.

Continuous Nauplii Harvesting

- Innovations in pond systems will enable continuous harvesting of live nauplii (Instar I), eliminating the need for cyst production (Bwala et al. 2018)
- This method will ensure a fresh, immediate feed source, improving efficiency and lowering production costs.
- Farmed nauplii are expected to have a better nutritional composition than their wild alternatives as a result of which the nauplius enrichment technique might become redundant.

Animal Feeds

- Artemia biomass will present as a sustainable, high-quality protein source to partially replace fish meal in terrestrial, aquatic, and other animal feeds.
- This will reduce reliance on wild-caught fish and support marine ecosystem conservation.
- Artemia biomass is expected to be used in the production of animal feed pellets, such as for tiger shrimp (*Penaeus monodon*) (Anh 2009).

Human Nutrition

- Artemia-derived protein and other nutrient-rich compounds have the potential to be used as ingredients in human food products (Ronsivalli, Philip, and Simpson 1987).
- Initial trials (Hoa Sorgeloos 2020;) and recipes (Syeda 2023) indicate that Artemia will become a viable alternative protein source. This emerging food category is projected to grow significantly in the coming years, competing with plant-based proteins and terrestrial insect proteins, such as black soldier fly.

Artemia farming offers local value capture by utilizing degraded or saline land, making it a natural fit for decentralized feed production models. With biomass production costs potentially below USD 1 per kg (wet), it competes favorably with black soldier fly and other alternative proteins. While challenges remain—such as quality standardization, regulatory inclusion, and processing infrastructure—these are addressable with targeted investment.

In Africa, where aquaculture is expanding rapidly—particularly in tilapia and catfish production—along with livestock production, Artemia biomass presents an untapped opportunity to partially replace fish meal in formulated feeds. In Zambia, for example, feed demand is substantial: the domestic aquafeed industry has the capacity for over 100,000 tonnes annually. Nigeria also has potential for Artemia to replace costly imported ingredients. While Zambia has no good production zones for Artemia, it could import from neighboring saline-rich countries like Namibia and Botswana, procuring a supplementary protein source for early-stage or specialty feeds

In short, Artemia biomass could help close the protein ingredient gap in global aquaculture and livestock feed systems, particularly in salt-affected, import-dependent countries. Its alignment with local feed resilience, land rehabilitation, and sustainable protein strategies makes it a strong candidate for future investment.

11

EMERGING APPLICATIONS - HUMAN FOOD

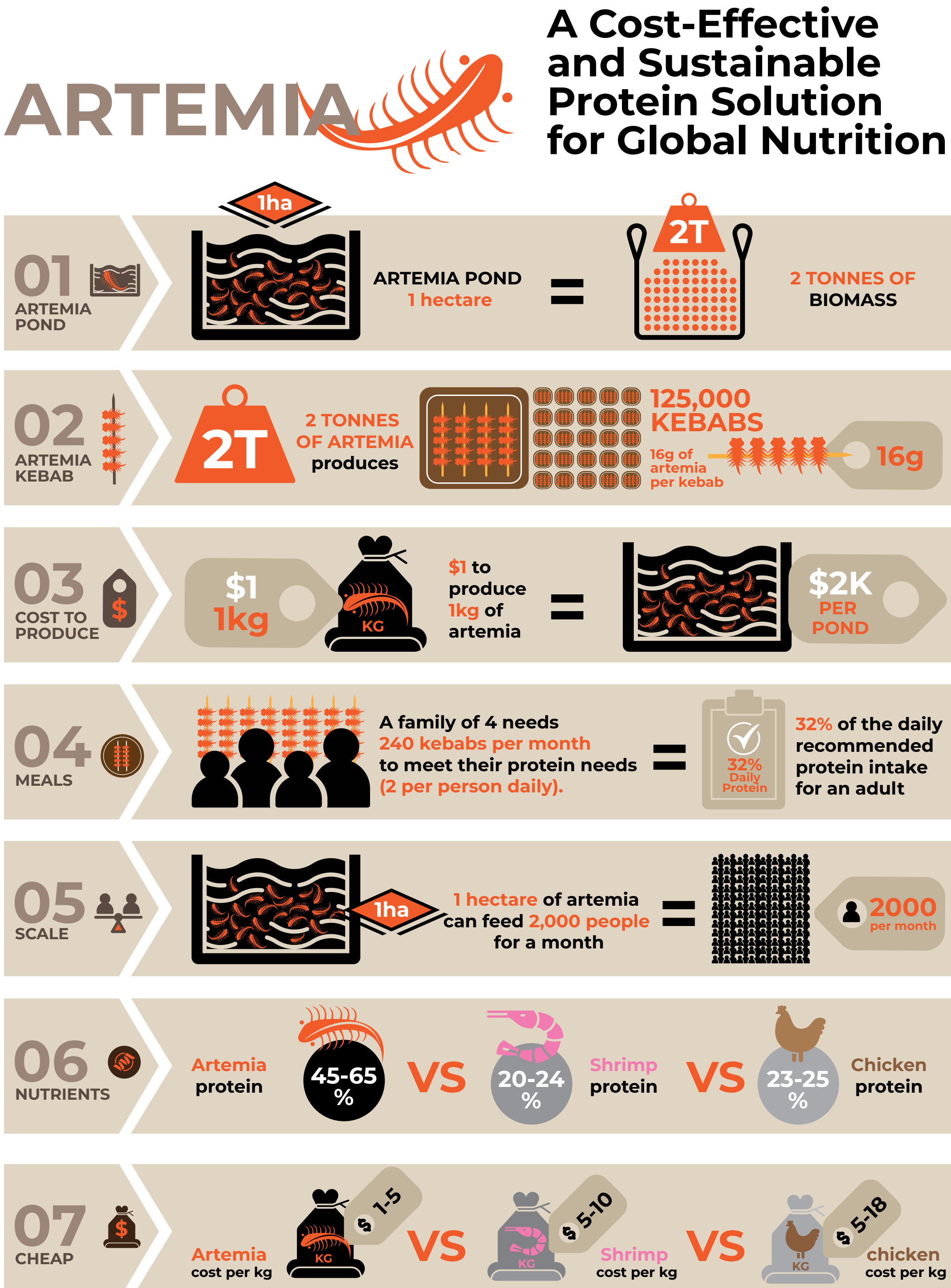
Artemia is also being recognized as a high-value protein source that may have direct applications as a nutritionally valuable food for humans. With its ability to thrive in saline, non-arable environments and produce protein-rich biomass in under two weeks, Artemia offers a potentially powerful, climate-resilient food solution. Its unique nutritional profile—up to 60–65 percent protein (dry weight), high omega-3 fatty acid content, and rich micronutrient density (iron, zinc, selenium, and vitamin B12)—makes it comparable to or superior to other animal-source proteins.

Nutritional analyses from pilot studies in Bangladesh and Viet Nam show that 100 g of dry Artemia powder provides up to 60 g of protein—higher than beef (26 g), shrimp (24 g), or chicken (27 g)—as well as 250 percent of the recommended daily intake (RDI) of iron and over 400 percent of the RDI of eicosapentaenoic acid (EPA) (a critical omega-3 fatty acid). Just 32 g of Artemia in a kebab delivers 32 percent of an adult's protein RDI and nearly 450 percent of daily EPA needs. The biomass is easily digestible, neutral in taste, and highly versatile across food formats.

Factor	Artemia	Shrimp	Chicken
Market price (USD per kg)	**~1–5**	5–18	5–10
Protein Content (%)	**40–65**	20–24	23–25
Water Usage	**Low (Hypersaline environments)**	High	High
Land Requirement	**Minimal**	Medium	High
Sustainability	**High**	Medium	Low

In Bangladesh, one hectare of integrated Artemia-salt farming can yield up to 4 tonnes of biomass per dry season. This equates to

- Over **160,000 meals** fortified with Artemia per hectare per season,
- **1 hectare** providing the protein needs for over 500 people for a month, and
- Cost of production being less than **USD 1 per kg** wet biomass, making it cheaper per protein unit than chicken or fish.



Food innovations in Bangladesh and Viet Nam include Artemia-based omelets, kebabs, porridges, seasoning powders, and biscuits. Research and development (R&D) labs in Thailand are now testing Artemia as a base for protein powders, fortified snacks, curries, meatballs, and therapeutic nutrition packets. In regions with high rates of anemia or child stunting, Artemia could serve as a scalable ingredient in maternal and child health programs that could be readily multiplied in local production systems near high saline environments.

Importantly, Artemia cultivation does not compete with conventional agriculture. It can be integrated into salt pans or saline land otherwise deemed unproductive. This creates significant potential in regions like West and Central Africa, Central Asia, the Middle East, and South Asia, where food insecurity and salinity-affected land often co-exist. Production can be paired with solar salt operations or wastewater reuse in climate-affected areas.

Despite its potential, Artemia faces regulatory and market barriers. Few countries formally recognize Artemia as a food-grade ingredient, and consumers are generally not aware of nor have cultural barriers to eating it. The value chain for post-harvest processing (drying, sterilizing, and packaging) remains underdeveloped. Investment is needed to build out infrastructure, support food safety trials, and raise consumer awareness. However, the market opportunity is significant, including arid, malnourished rural settings and nutrition programs and climate-adapted food systems.

With rising demand for sustainable, nutritious foods, Artemia biomass is an opportunity for significant investment and growth. It potentially offers governments and investors a triple-win: a climate-smart protein, a circular economy solution, and a pathway to nourish millions using saline land that was once considered barren.

SCALING ARTEMIA OMELET PRODUCTION: UNLOCKING A SUSTAINABLE PROTEIN SOURCE

Artemia Omelet

The Artemia omelet recipe was originally developed in Viet Nam and then in Bangladesh and Thailand. While a traditional omelet made with eggs already provides some protein, an Artemia omelet offers much higher protein. For instance, much higher protein content: 20–22 g per serving (2 eggs + 20 g Artemia), compared to ~12 g (2 eggs) in a regular egg omelet. Moreover, the artemia omelet is a rich source of essential micronutrients, including iron, calcium, zinc, and essential fatty acids. See Annex 1 for the recipe and nutritional content

Estimating Omelet Production from 1 Hectare of Artemia Farming

A 1-hectare pond can produce 2–4 tons (2,000–4,000 kg) of Artemia per month (4 tons of live weight biomass; in dry weight this means 400 kg per hectare monthly), allowing for large-scale, sustainable protein production. Compared to traditional livestock and aquaculture systems, Artemia reaches full maturity in just 2 weeks, making it one of the fastest-growing protein sources available. Considering that

- one 170 g Artemia omelet contains 20 g of Artemia
- 1,000,000 g (1,000 kg) of Artemia, at 20 grams per omelet= 50,000 omelets

This means that a 1-hectare Artemia pond (for example, if we say at least 2–3 tons of live artemia biomass, which would be around 800–1,200 kg dry weight of artemia production per month from 1-hectare) can supply about 100,000 omelets per month, offering a sustainable and nutrient-dense protein source to thousands of people.

Meeting Nutritional Needs at Scale

Each 170 g Artemia omelet provides a balanced source of protein, fats, and essential micronutrients, making it an excellent dietary addition. With 50,000 omelets per month, the potential impact includes

- **Food security enhancement:** If one person consumes one omelet per day, 50,000 people could be served per month;
- **High-protein access:** With 24.8 g of protein per omelet, this production model could significantly reduce protein deficiency in undernourished communities; and
- **Cost-effective nutrition:** Artemia is affordable and farmable in saline environments, reducing reliance on expensive meat-based proteins like shrimp, fish, or beef.

Future Potential and Scaling Up

If more hectares of Artemia ponds are developed for human food applications, the potential to combat malnutrition and food insecurity becomes even more significant. For example:

- **10 hectares of Artemia ponds** = 500,000 omelets per month
- **100 hectares of Artemia ponds** = 5 million omelets per month

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ENVIRONMENTAL BENEFITS AND CHALLENGES

Artemia farming provides environmental advantages, particularly when compared to conventional animal protein production. Unlike intensive livestock or aquaculture systems, Artemia can be cultivated in hypersaline environments—lagoons, salt pans, and degraded soils—where few other food production systems can thrive. This allows Artemia production to minimize land-use conflicts and contribute to the rehabilitation of marginal areas. Existing landscapes—saline ponds and salt pans—can be used more productively, rather than new habitat conversion.

One of Artemia's key environmental benefits is its low input demand. Artemia requires no freshwater or formulated feeds. Instead, they feed on naturally occurring microalgae, organic detritus, and bacterial bioflocs that develop on agriculture waste products, such as organic materials and fiber-rich waste of different crops such as rice bran and casava, in saline ponds, making their farming inherently circular and resource-efficient. When integrated into solar salt production systems or wastewater reuse operations, Artemia farming contributes to waste valorization, better resource use, and improved land-use efficiency.

For investors and governments seeking climate-smart agriculture models, Artemia offers a new choice. Its cultivation turns unproductive, saline land into protein-producing landscapes, converting agricultural waste into high-protein feeds. There is also strong alignment with sustainable landscape management goals and nature-based climate solutions. Artemia farming can be incorporated into green investment portfolios targeting carbon reduction, blue carbon strategies, and resilient food systems. Solar salt operations, often underutilized outside peak salt harvesting seasons, can be retrofitted or dual-purposed for Artemia cultivation—generating additional income and reducing downtime.

Because Artemia are sensitive to salinity and cannot survive in freshwater or normal marine systems, they pose virtually no risk as an invasive species. Even if introduced to new areas, they cannot establish themselves without hypersaline conditions. This makes them ecologically safer to farm than many introduced aquaculture species. Their cultivation can coexist with migratory bird conservation zones and saline wetland ecosystems, as seen in the salt flats of Iran and China.

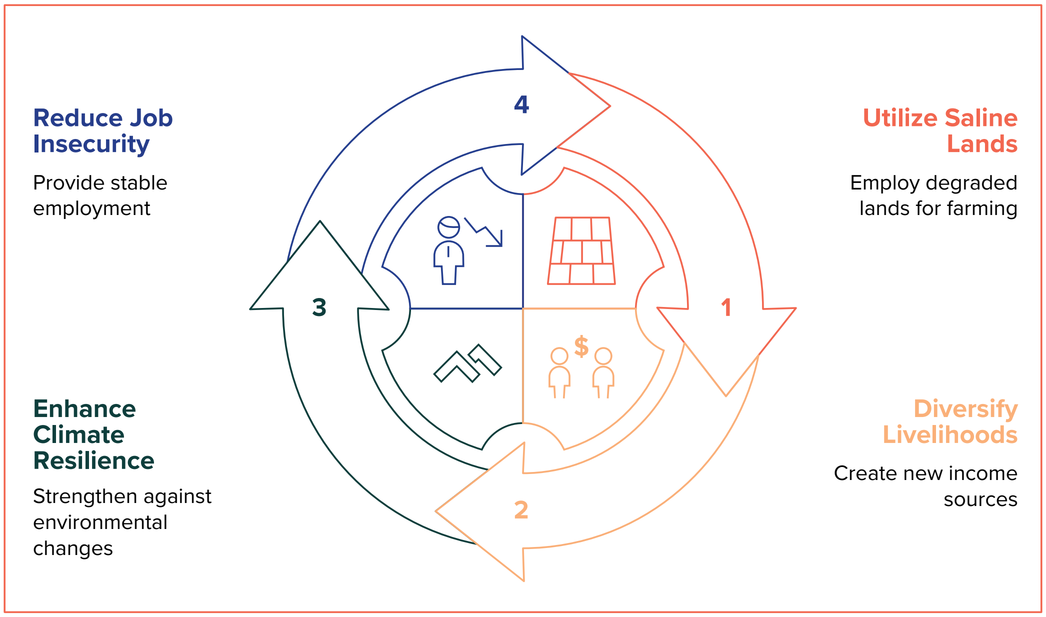
Carbon emissions from Artemia farming are also minimal. No specialized heating, aeration, or artificial feed inputs are required, and solar evaporation can provide the energy needed for drying in many locations. Comparative lifecycle assessments suggest that Artemia production emits significantly less CO_2-equivalent per kg of protein than poultry, beef, or aquaculture feed crops like soy.

However, environmental challenges remain. Excessive nutrient enrichment in Artemia ponds can lead to algal blooms, brine management must be carefully controlled to prevent salinization of adjacent lands, and harvesting without proper sediment control can disturb local ecosystems. In some coastal zones, Artemia pond expansion may also conflict with mangrove conservation or aquifer recharge areas. Careful site selection, zoning, best management practices, ecological monitoring, and regulatory alignment are therefore crucial. Opportunities exist to build Artemia systems into climate-smart agricultural investments, nature-based solutions frameworks, and blue carbon investments, especially where Artemia ponds can be integrated into coastal landscapes, as salt marsh restorers, sediment traps, or saline land rehabilitation zones.

13

SOCIAL BENEFITS AND CHALLENGES

Artemia farming offers a pathway to inclusive development in saline-prone, arid, and low-income regions. Experience in Asia shows benefits to employment generation, household resilience, and livelihood diversification in areas where traditional agriculture or aquaculture is not viable. By integrating Artemia into saltworks, saline aquaculture, or degraded land systems, communities may unlock new income streams and reduce seasonal job insecurity.



Experiences from Viet Nam and Bangladesh show the opportunity. In the Mekong Delta, over 500 households engage in Artemia farming across 700–800 ha of saline ponds, generating up to 2,000 seasonal jobs, with women making up nearly 20 percent of the processing workforce. Each hectare of pond creates work for 2–3 people, often as casual or seasonal laborers. In Soc Trang province, annual household income from integrated Artemia systems averaged USD 5,200–6,500, with up to 70 percent coming directly from Artemia cysts.

In Bangladesh, 54 farmers managed 5 ha, producing over 6.7 MT of biomass in a single season. With total revenues of around USD 40,000, each farmer earned an average of USD 740 (15 percent increase) in just one dry season. Total incomes increased by 2.5 times once the additional fish and shrimp cultivated in the rainy seasons were factored in on the baseline average of USD 4,800 earned from crude salt farming, helping families withstand price volatility and climate shocks. Women in Bangladesh have also been trained in Artemia-based food processing and recipe development, contributing to household nutrition and income.

Viet Nam Delta

500+ Households - 700 ha -
2,000 seasonal jobs
20% women in processing
annual house hold income USD
5,200–6,500

Bangladesh Farmers

50 farmers - 5 ha - USD 40,000
income/1 season
15% income boost
women in food processing

Thailand Farms

Salt farm integration
Year-round rmployment

Case studies suggest that a 1-hectare Artemia pond can yield 2–5 tonnes of biomass per season and create employment for up to three people. Artemia farming is especially suitable for low-income communities due to its low capital requirement and short production cycle. It is ideal for women, youth, and seasonal workers. In Thailand, salt farm integration requires manual harvesting of Artemia, creating additional jobs during the dry season. Meanwhile, during the wet season, many of these systems switch to shrimp or fish farming, supporting year-round employment.

These systems are particularly beneficial for artisanal salt farmers, who often rely on a single source of income during a narrow harvest window. Artemia cultivation allows them to extend their productive season and earn revenue from cysts, biomass, and brine sales, buffering against failed salt harvests and poor weather conditions. In multiple regions, integrated Artemia-salt-aquaculture models have doubled or even tripled farmer incomes, while also providing affordable protein to local markets.

However, Artemia farming remains unfamiliar in many new geographies. Barriers such as lack of training, processing infrastructure, and market access need to be addressed. Without policy and catalytic early-stage business support, there is a risk that benefits may be captured primarily by export-oriented enterprises. Artemia can be integrated into inclusive development strategies through training, finance, and cooperative models.

14

GOVERNANCE FRAMEWORKS AND ENABLING ENVIRONMENT

Effective governance is essential for unlocking Artemia's potential across food, feed, and environmental markets. As a relatively underdeveloped aquaculture opportunity, Artemia farming currently operates in a regulatory grey zone in most countries. Few national policies formally recognize Artemia as a strategic commodity, and fewer still have tailored legal, quality, or safety standards for its farming, processing, or trade.

Of 15 countries reviewed during this research, Artemia is typically bundled under general aquaculture or salt legislation, if mentioned at all. In most regions—including Africa, the Middle East, and South Asia—there are no guidelines for seed quality, biosecurity, or cyst and biomass certification. This poses a barrier to scaling and risks undermining farmer confidence, product quality, and investor interest.

Country case studies provide useful guidance on the enabling environment for Artemia aquabusiness:

- In Viet Nam, Artemia farming benefits from strong institutional support through research centers, hatchery standards, and provincial policy frameworks.
- In Bangladesh, the government has included Artemia under broader aquaculture development programs, and the government has supported its integration into national nutrition and livelihood strategies.
- In China, Artemia is managed under a broader salt industry licensing system but lacks environmental compliance standards tailored to aquaculture.
- In Kenya, the government has yet to define a national Artemia policy, but county government research institutions are actively piloting its inclusion in local blue economy strategies.

Certification remains a key gap. There is currently no internationally recognized certification for Artemia biomass or cysts, though some private companies have adopted voluntary standards or traceability protocols and FAO has requested the IAAC to develop guidelines for cyst certification that could later be adopted in certification schemes Price differentiation between certified and non-certified cysts is substantial—up to 30–50 percent—suggesting strong incentives for developing formal product quality frameworks. Certification could also help Artemia producers tap into premium feed or human food markets, where safety, traceability, and branding are essential.

Investment-friendly governance would include

- Legal recognition of Artemia farming as a formal activity;
- Guidelines on licensing, seed handling, and biosecurity;
- Cyst and biomass grading standards;
- Inclusion in national food safety, livestock feed, and aquaculture regulations; and
- Supportive customs codes and trade classifications to help streamline exports and imports, especially for new products like biofortified cysts or Artemia-based foods.

Beyond regulations, public investment is needed in institutional capacity, extension services, research, and infrastructure. Government support for Artemia hatcheries, farmer cooperatives, and certification schemes could reduce entry barriers and expand inclusion. Development partners and financial institutions can also play a role in de-risking investments through blended finance, insurance, and incubation programs.

A well-defined enabling environment is not only essential for scaling Artemia production, it is critical for ensuring the sector develops equitably, sustainably, and in line with national development priorities.

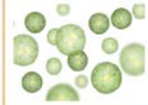
15

COMPETITION AND RISKS

While Artemia holds significant promise, it operates within a competitive and risk-laden environment that must be clearly understood by investors and policy makers. As a live feed input and potential protein source, Artemia faces direct competition from alternative organisms, evolving market dynamics, and environmental uncertainties.

In the hatchery sector, Artemia competes with other live feeds like rotifers and copepods, which are increasingly produced using advanced biotechnologies. Hatcheries in some countries are also experimenting with formulated microdiets as total replacements for Artemia nauplii, particularly in marine finfish. However, Artemia remains the gold standard for shrimp and many high-value fish species due to its hatchability, digestibility, ease of storage, and biosecurity profile. For example, while rotifers are easier to mass-produce, they have significantly lower lipid and protein content and require algae or special emulsions for enrichment, adding operational complexity. Copepods are nutritionally superior but are expensive and difficult to mass-produce at commercial scale.

In terms of cost, Artemia cysts typically range from USD 30–200 per kg depending on origin and hatch-out rate. This compares favorably to copepods (often exceeding USD 150–200 per kg) but on par with enriched rotifers (USD 50–80 per kg including algal feed). For aquafeed applications, dried Artemia biomass can be produced locally for under USD 1 per kg wet weight, competing with fish meal (USD 1.2–1.8 per kg), black soldier fly (USD 1.5–2.5 per kg), and spirulina (USD 5–10 per kg). Moreover, Artemia's unique production in saline, otherwise unproductive, landscapes offers environmental cost advantages not factored into commodity prices.

Live Feed	Artemia (cysts/nauplii)	Rotifers (*Brachionus* spp.)	Copepods	Daphnia	Moina	Ciliates	Microalgae
							
+ Pros	+ Easy to store as dry cysts; long shelf life (years). + Quick hatching (24 hours); consistent nauplii production. + Biosecure product + Nutritionally rich and digestible for a wide range of species. + Suitable for both marine and freshwater larvae.	+ Highly scalable and easy to culture in hatcheries. + Very small size makes them suitable for smaller larvae (e.g., marine fish). + Cost-effective and widely used for fish hatcheries.	+ Superior nutritional profile, rich in essential fatty acids (EPA, DHA). + Small size and natural swimming behavior stimulate fish larvae feeding. + High digestibility and enhanced survival rates for fish larvae.	+ Easy to culture in freshwater systems; rapid reproduction. + Cost-effective for small-scale operations. + Can be used as live or frozen feed.	+ Smaller size compared to Daphnia; suitable for small freshwater larvae. + Easy to culture in nutrient-rich freshwater.	+ Extremely small size; ideal for the earliest larval stages of small fish. + Simple to culture in small batches for hatcheries.	+ Essential for filter feeders and bivalve hatcheries. + Easy to scale and culture for specific species.
– Cons	- Fluctuating nutritional composition of wild sources. Dependence on wild harvesting raises sustainability concerns. - Limited natural availability during poor harvest seasons. - High production cost for farmed Artemia compared to wild harvest.	- Nutritional value depends on enrichment (requires additional effort). - Sensitive to environmental fluctuations during production. - Can have biosecurity issues (bacterial contamination)	- Difficult to culture at large scale; high production costs. - Highly labor-intensive for consistent supply. - Mostly limited to research and niche hatcheries. - Can have biosecurity issues (bacterial contamination)	- Limited to freshwater aquaculture; not suitable for marine larvae. - Requires enrichment to meet full nutritional needs. - Often biosecurity issues (bacterial contamination)	- Similar limitations to Daphnia (freshwater-only). - Requires nutrient supplementation for optimal growth. - Often biosecurity issues (bacterial contamination)	- Very low nutritional content compared to Artemia or copepods. - Limited to very small larvae and short-term feeding.	- Low protein content; insufficient as a standalone feed for larvae. - Production requires specialized infrastructure and high energy inputs.

Feed Source	Typical Cost (USD per kg)	Notes	Relative Cost
Artemia cysts (wild/farmed)	30–200	Premium hatchery feed; prices vary by origin and hatch-out rate.	(low–medium)
Artemia biomass (dried)	<1 (wet weight basis)	Produced in saline ponds; low cost, locally adaptable, competitive with fish meal.	(very low)
Fish meal	1.2–1.8	Derived from capture fisheries; prices influenced by stocks and regulation.	(low–medium)
Black Soldier Fly meal	1.5–2.5	Produced from organic waste; emerging sector with scale-up costs.	(low–medium)
Spirulina	5–10	High-value algal protein; controlled production leads to higher costs.	(medium–high)
Enriched rotifers	50–80 (including algal feed)	Hatchery feed requires continuous algal culture; high labor and input costs.	(high)
Copepods	>150–200	Premium marine larval feed; complex culture and high production costs.	(very high)

In the broader protein and feed market, Artemia biomass competes with established and emerging alternatives such as fish meal, soy, insect meal, spirulina, and single-cell proteins. Artemia's edge lies in its superior digestibility, balanced amino acid profile, and high levels of omega-3 fatty acids. However, large-scale competition will depend on post-harvest efficiency and regulatory pathways for inclusion in commercial feeds and food products.

Artemia farming systems are vulnerable to shifting salinity levels, irregular rainfall, and evaporation patterns—factors that could disrupt production cycles. In wild harvest systems, these effects are already visible in the GSL, where declining water levels have reduced productivity. For farmed systems, good site selection and adaptive water management are essential to minimize climate risk.

Biosecurity is another concern. Artemia ponds can become contaminated with pathogens or predators if not properly managed. The lack of uniform standards for seed and broodstock quality, especially in emerging farming regions, may also limit cyst viability and biomass productivity. Ensuring consistent quality will depend on hatchery support, genetic selection, and certification.

Market volatility, particularly for wild-harvested cysts, is also a concern. Prices can swing by over 50 percent between seasons depending on supply disruptions, weather, and global shrimp hatchery demand (or shrimp disease outbreaks). This can make planning and investment in the Artemia sector risky for new entrants without storage or contract mechanisms.

16

TECHNOLOGIES AND STAKEHOLDERS

The growth of Artemia farming has been driven by a mix of traditional knowledge, applied research, and evolving technologies across the value chain. Key advances in Artemia production systems include improvements in strain selection, hatchery and pond management, harvesting equipment, and post-harvest processing—all of which help reduce input costs and improve yield and quality.

Technologies used in Artemia production vary by country and business model. In Viet Nam, hatcheries rely on improved domesticated strains, innovative hatching systems, and careful salinity control to boost cyst quality. China's solar salt-based Artemia farms use gravity-fed brine management systems, lined ponds, and manual cyst harvesters adapted for high-efficiency collection. Thailand and Kenya are pioneering mobile biomass harvesting systems and simple drying units suitable for inland saline zones.

Innovations are emerging in live biomass handling, paste and meal conversion, and cold chain integration. In Bangladesh, low-cost dryers and sieving equipment are used to support artisanal producers. In commercial systems, feed companies are exploring de-fatting, pelletizing, and nutrient enrichment technologies to create value-added Artemia products for aquafeeds, poultry, or pet food markets. Enrichment technologies are also being used to enhance Artemia with omega-3 fatty acids, selenium, and vitamin A for both feed and human food applications. Cysts can be biofortified with essential fatty acids or probiotics to improve hatch-out performance and larval health in hatcheries, while biomass can be conditioned through targeted feeding with algae-based media or microbial additives to enhance nutritional value.

Digital platforms and Internet of Things (IoT)-enabled salinity sensors are also being tested in pilot projects, particularly in China and pilot farms in East Africa. These allow producers to monitor pond conditions in real time, reduce water losses, and fine-tune harvest timing. As farming scales up, technologies for water recirculation, species separation, and climate-resilient pond design will become increasingly important.

Farming system innovations

1. Banchong Farm | Thailand | Intensive farming system

2. Suntri Farm | Thailand | Semi-Intensive farming system

3. Artemia4Bangladesh | Bangladesh | Artisanal culture, social engagement, human consumption

Technology innovations

4. INVE Aquaculture | Various countries | Hatchery equipment, animal health, energy saving

5. I&V-Bio | Various countries | Specialty cysts

6. I&V-Bio and Codemet | Various countries | Live feeds

7. Aqua West | Viet Nam | Live feed

8. INVE Aquaculture, Skretting, Biomar, BernAqua | Various countries | Nutritional enhancement of Artemia nauplii

9. Ocean Star International and Artemia World | United States, Russia | Aquaculture feeds

The stakeholder landscape is equally diverse. It includes artisanal salt farmers, shrimp hatcheries, women-led cooperatives, feed manufacturers, R&D institutions, government aquaculture departments, and development donors. Regional and international institutions also play a critical role. The Network of Aquaculture Centres in Asia-Pacific (NACA) has supported Artemia knowledge exchange and research dissemination across Asia, while the IAAC brings together researchers, producers, and policy makers to coordinate global action on Artemia farming standards, market development, and investment. A full mapping of companies, technologies, hatchery equipment suppliers, processors, and investors involved in Artemia production can be found in Global Inventory Report of Artemia Stakeholders.

Scaling the sector will require coordinated innovation and investment across this ecosystem—from pond design to processing to distribution. Continued technology development, when paired with inclusive business models, could help build a global Artemia sector that is efficient, equitable, and environmentally smart.

17

BUSINESS CASES AND SCALABLE MODELS

Building on country-specific value-chain analyses, four distinct and investable Artemia production models have emerged. Together they illustrate how an Artemia aquabusiness can be scaled across contexts ranging from large industrial saltworks to inclusive smallholder clusters. Each model presents a different cost structure, production potential, and investment profile, offering a practical road map for both private investors and public programs seeking to catalyze growth in the sector.

Category[7]	China 	Thailand 	Viet Nam 	Bangladesh 
Name of Business Model and Products	China Artemia Biomass and Cysts in Large Solar Saltworks Model	Thailand Artemia Biomass Pond Farming	Viet Nam Artemia Cysts and Salt Pond Farming	Bangladesh Year-round Integrated Artemia Salt Farming
Cycle Time	April to November (seasonal production)	Year-round operation possible, peak in dry season	4–5 months (dry season)	January–May (dry season) or year round if doing tilapia/shrimp in rainy season
Tons per Hectare per Cycle	Cysts: Large salt ponds (30–60 ha per pond) Biomass: High-yield, large-scale collection	Biomass: 2–4 tons per ha per cycle	Cysts: 50–70 kg per ha (150–200 kg in intensive systems) Biomass: 4–5 tons	Cysts: ~17 kg per ha Biomass: 1.3–1.4 tons per ha
Cost per Kilogram	Biomass: USD 0.30 per kg	USD 0.15–0.50 per kg	USD 15–20 per kg	Around USD 36 per kg for cysts and USD 1.4 per kg for biomass
Selling Price (USD per kg)	Cysts: Premium price (150% higher than inland cysts Live biomass: USD 1–2 per kg	Live biomass: USD 1.75–1.78 per kg Frozen biomass: USD 1.50–1.63 per kg	Cysts: USD 200 per kg (high-quality Viet Nam cysts) Imports: USD 50–100 per kg	Cysts: USD 50–100 per kg Live biomass: USD 4–5 per kg
Revenue per Hectare	USD 6,000–30,000 per year	Up to USD 38,000 per farm per year USD 3,500–9,600	Cysts: USD 10,000 per ha per season Biomass: Additional revenue stream	Estimated USD 8,000 per ha per season
Profit Margin	30–50%; stable due to high demand; cysts sold at a premium due to better hatchability and nutritional value	Profit until end-user can be 50–90%, with processors taking 30–40%	30–50% for farmers but processors take a further 60%, meaning total margin is over 90%	40–50% but variable and dependent on local demand and production efficiency

7 These maps are for illustrative purposes and do not imply the expression of any opinion on the part of the World Bank concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries.

China - Solar Saltworks Integration: Large solar saltworks co-produce Artemia cysts and biomass at very low unit cost (~USD 0.30 per kg). Premium cyst prices (>USD 100 per kg) yield 30–50 percent margins when operated above 100 ha.

- **Investment entry points:** Retrofit salt ponds for dual salt-Artemia use; upgrade fertilization and pumping systems; shared processing and quality assurance (QA) labs.
- **Bank priorities:** De-risk infrastructure; support standards, biosecurity, and salt-aquaculture policy integration. Retrofit salt ponds, improve pumping/fertilization, shared QA labs.

Thailand - Biomass Pond Farming: A semi-intensive, year-round biomass model located near hatcheries; production costs USD 0.15–0.50 per kg and >50 percent profit margin make it one of the most bankable SME aquabusinesses.

- **Investment entry points:** Cluster finance for cold-chain and aeration; training on salinity and fertilization management; digital water-quality monitoring.
- **Bank priorities:** Short-term credit lines, SME guarantees, and cluster-based extension. Focus on pond lining, decapsulation units, climate-smart fertilization.

Viet Nam - Premium Cyst and Biomass Salt Ponds: Seasonal production yields 50–70 kg cysts (>150 kg intensive) and 4–5 tonnes biomass per ha. Despite higher costs (USD 15–20 per kg), high-quality cysts command ~USD 200 per kg and 30–60 percent profits.

- **Investment entry points:** Pond rehabilitation, brine storage, and decapsulation/processing units.
- **Bank priorities:** Finance QA laboratories, certification systems, and climate-smart fertilization R&D. Working-capital finance, digital monitoring, cold-chain hubs.

Bangladesh - Integrated Smallholder Salt-Artemia: Inclusive smallholder clusters show strong returns (cost-benefit ratio 1.96) and low entry costs. Biomass sells at USD 4–5 per kg versus a production cost of USD 1.4 per kg; cysts sell at USD 50–100 per kg. Proven climate-resilient model for saline zones.

- **Investment entry points:** Micro-capex (pond deepening, pumps); training and market linkages.
- **Bank priorities:** Inclusive finance for clusters; support seed and brine services; women-led co-ops. Micro-leasing for pumps, training, and community brine systems.

Indicative KPI Benchmarks

KPI Category	Range / Target Value	Competitive Drivers
Yield (biomass)	2–5 t / ha / cycle	Optimised salinity & fertilisation
Yield (cysts)	50–150 kg / ha	Pond depth + strain selection
Production cost (biomass)	US $0.15–1.4 /kg	Scale and energy efficiency
Profit margin	30–70 %	Market linkages & QA
Payback period	1–2 years	Low CAPEX requirements
Employment density	1–3 jobs / ha	Processing and cluster models
Gender participation	30–50 % in processing possible	Co-ops and SME ownership

Investment Pathways for Scalable Artemia Models

The four business models identified—industrial (China), semi-intensive (Viet Nam), SME-based (Thailand), and smallholder (Bangladesh)—represent complementary investment pathways rather than sequential stages. Each model can be replicated or hybridized depending on the local resource base, investor appetite, and policy environment.

1. Industrial Integration Pathway

- **Context:** Mature salt or aquaculture industries with reliable infrastructure (for example, China and Middle East).
- **Objective:** Retrofit or co-develop solar saltworks for integrated Artemia cyst and biomass production.
- **Scale requirements:** 30–100 ha contiguous ponds; yields >5 tonnes biomass per ha per cycle; cyst yield 100–150 kg per ha.
- **Investment logic:** Economies of scale lower costs to ~USD 0.30 per kg biomass; highest ROI once brine pumping and drying are shared with salt operations.
- **Potential replication:** Coastal salt belts of Egypt, Namibia, Saudi Arabia, and Iran.
- **Key needs:** Capital finance for retrofitting, policy integration of salt–aquaculture use rights, and QA and export certification systems.

2. Semi-Intensive Premium Pathway

- **Context:** Medium-scale farms with seasonal salinity (for example, Viet Nam).
- **Objective:** Combine cyst and biomass production for domestic and export markets.
- **Scale requirements:** 5–20 ha modular ponds; 4–5 tonnes biomass per ha; cyst yield 50–100 kg per ha.
- **Investment logic:** Moderate capex (<USD 25,000 per ha) achieves 30–60 percent profit margins when linked to processing and certification.
- **Potential replication:** India, Indonesia, Peru, and Iran.
- **Key needs:** Finance for pond lining, decapsulation and drying units, and climate-smart fertilization.

3. SME and Cluster Pathway

- **Context:** Peri-urban or coastal SME zones with access to hatchery markets (for example, Thailand).
- **Objective:** Year-round Artemia biomass supply for hatcheries and ornamental feed.
- **Scale requirements:** 2–10 ha clusters; 2–4 tonnes biomass per ha per cycle; continuous production.
- **Investment logic:** Unit cost USD 0.15–0.50 per kg with 1–2 year payback; strong employment generation.
- **Potential replication:** Ghana, Kenya, Tanzania, and the Philippines.
- **Key needs:** Working-capital finance, digital quality monitoring, and cold-chain and extension services.

4. Smallholder and Inclusive Pathway

- **Context:** Artisanal salt or aquaculture systems in saline or degraded lands (for example, Bangladesh).
- **Objective:** Integrate Artemia into diversified livelihood systems for salt farmers and women's groups.
- **Scale requirements:** 0.5–2 ha units aggregated into 10–20 ha clusters; cyst yield 10–25 kg per ha.
- **Investment logic:** Low entry cost; cost–benefit ratio ~2; strong poverty-reduction and climate-adaptation co-benefits.
- **Potential replication:** West Africa, Mozambique, Pakistan, and Bolivia.
- **Key needs:** Micro-leasing for pumps, farmer training, community brine management, and cooperative marketing.

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INVESTMENT CRITERIA AND SCALING CONDITIONS

Further investment in expansion of Artemia aquaculture requires clear investment criteria and an enabling environment tailored to the specific characteristics of each model. Investors, policy makers, and development partners can use the following criteria to assess the viability and readiness of Artemia initiatives across contexts, from country to local levels.

Key investment criteria:

- **Saline land availability**: Access to coastal or inland saline environments with stable salinity levels above 60 ppt.
- **Water and brine management**: Reliable saline water sources and systems for seasonal or year-round brine control.
- **Locally available Artemia nutrient resource**: Organic substrates, waste/by-products of local agriculture products.
- **Market demand**: Existing or emerging hatchery, feed, or food markets that can absorb Artemia cysts or biomass.
- **Labor supply and inclusivity**: Availability of artisanal labor, interest from women's groups or youth, and potential for cooperative engagement.
- **Infrastructure and logistics**: Access to roads, drying or processing infrastructure, and cold chain (for biomass).
- **Policy and regulatory frameworks**: Supportive aquaculture, salt, or food safety regulations enabling Artemia production and trade.

Scaling conditions:

- **Low entry barriers**: Simplicity and affordability of technologies suited to smallholder adoption (for example, drying beds and paddle harvesters).
- **Public–private support**: Involvement of R&D institutions, nongovernmental organizations (NGOs), agribusinesses, or feed manufacturers in pilot deployment.
- **Extension and training**: Availability of technical assistance in pond management, seed quality, harvesting, and biosecurity.

- **Certification and quality standards**: Systems for grading, labeling, and traceability—especially for cysts and enriched biomass.
- **Climate resilience and circularity**: Integration into climate-smart farming, including salt reuse, wastewater recirculation, or solar drying.
- **Access to finance**: Microfinance, concessional loans, or blended finance mechanisms for producers and SMEs.

These criteria are not rigid—they should be adapted based on geography, end market, and business model. For instance, cyst-focused models may prioritize quality control and export logistics, while biomass-oriented systems may emphasize feed formulation partnerships and local demand mapping.

Hypersaline agro-ecosystems - lakes, ponds, salt pans, salt works

Small-scale (artisanal) salt farmers in saline zones

Markets and value chains, such as domestic or regional aquaculture markets and alternative uses

Novel applications in animal feeds and human food: segmented by income

Enabling regulatory, research and governance systems

Alternative markets (poultry or livestock feed, boutique foods, ornamental fish)

Clear, investor-aligned criteria and early-stage support mechanisms are critical to ensure that Artemia farming evolves from a niche opportunity to a mainstream, scalable solution across multiple value chains.

Building on the business models described in Section 17, this section identifies the enabling environment and investment readiness factors necessary to operationalize Artemia aquaculture at scale. The criteria are designed to guide both public and private actors in selecting, financing, and sequencing Artemia investments across diverse geographies.

Framework for Investment Readiness

Criterion Cluster	Description / Function	Indicative Metrics / Thresholds	Illustrative Policy or Program Instruments
1. Governance & Regulation	Land tenure, water rights, salt-aquaculture integration, product standards.	Legal clarity on pond tenure; national cyst QA protocols.	Aquaculture zoning; salt-aquaculture co-use laws; certification schemes.
2. Infrastructure & Logistics	Ponds, pumps, drying yards, access roads, cold chain.	Capex < US $25 000 / ha; logistics cost < 10 % of output value.	PPPs, concessional loans, green-infrastructure funds.
3. Access to Finance	SME credit, micro-leasing, investment guarantees.	Interest < 10 %; repayment ≤ 2 yrs; > 30 % cluster coverage.	Blended finance, DFI credit lines, matching grants.
4. Technology & Knowledge Systems	Strain selection, QA labs, extension, R&D.	Hatch-out > 85 %; adoption rate > 60 % in clusters.	Public R&D grants, innovation accelerators, digital advisory tools.
5. Social & Environmental Safeguards	Inclusion, jobs, climate resilience.	≥ 30 % women employed; E&S compliance.	Gender-responsive training, climate adaptation plans.

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INVESTMENT POTENTIAL IN SELECTED REGIONS

The study has looked at the investment potential across major regions, with the following findings in summary.

Asia Growth Opportunities

Asia is both the engine and bottleneck of the global Artemia trade—home to the world's largest aquaculture producers and a fast-growing hatchery sector, yet still dependent on imports for high-quality Artemia cysts. While China, Viet Nam, Thailand, and Bangladesh are more established, a broader view reveals new frontiers for Artemia scale-up across the continent, especially where saline lands, strong feed demand, and salt industries intersect. The study identifies the following opportunities in Asia:

- **India** is the world's second-largest farmed shrimp exporter and imports over 500 tonnes of Artemia cysts annually, with extensive areas of salt pans and extensive saline groundwater—ideal conditions for Artemia farming. The country's aquafeed industry is valued at over USD 1.2 billion. Investment opportunities lie in cyst farming for hatcheries and biomass integration for local feed mills.
- **Indonesia** produces over 2.5 million tonnes of aquaculture shrimp and fish annually and has more than 100,000 hectares of salt-producing land. Artemia demand is estimated at over 600 tonnes of cysts per year.

- **Pakistan** has one of the world's largest inland salt reserves, with over 1.5 million tonnes of salt produced annually, yet Artemia is not currently farmed at scale. Artemia biomass farming could support localized feed initiatives and smallholder integration in Sindh and Balochistan.
- The **Philippines** hosts a large milkfish and shrimp hatchery network with growing demand for live feeds. Artemia cysts are imported, and production remains negligible. Integrating Artemia into nursery feed systems could reduce costs and improve early-stage fish survival.

These emerging countries meet many of the investment criteria identified in Section 18 from saline land availability and strong aquaculture demand to alignment with circular food systems and feed resilience strategies. Tailored entry models—ranging from smallholder cyst farming to biomass-feed integration with salt cooperatives—could help Asia move beyond its current bottlenecks and solidify its role as a global Artemia leader.

Investment Potential in Africa - The New Frontier

Africa represents one of the most promising frontiers for Artemia farming, with large expanses of saline land, a growing aquaculture sector, and underserved feed markets. While current Artemia production remains limited, the continent hosts a variety of enabling conditions that align well with the investment criteria outlined earlier.

Countries with Established Salt Industries and Saline Infrastructure

Several African countries have large solar salt operations that offer ideal conditions for integrated Artemia farming.

- **Senegal** produces ~450,000 tonnes of salt annually, with around 150,000 tonnes produced by small-scale harvesters from solar pans. The salt sector provides livelihoods for an estimated 50,000 people.
- **Namibia.** Walvis Bay hosts industrial saltworks producing over 900,000 tonnes of salt annually, with significant infrastructure that could be leveraged for Artemia biomass production and export to inland hatcheries or feed processors.
- **Mozambique** has over 15,000 hectares of operational salt pans.

These areas could support cyst or biomass farming with minimal infrastructure upgrades, particularly when integrated with fish or shrimp systems.

Countries with Large Numbers of Artisanal Salt Farmers and Saline Soils

- **Kenya** has ~4,000 artisanal salt producers across the coastal belt, as well as saline lakes in inland regions.
- **Ghana** has several thousand smallholder salt workers near Ada and Songor.
- **Tanzania**, **Ethiopia**, and **Sudan** have large tracts of saline or alkaline soils with limited use, offering potential for Artemia expansion.

In these settings, Artemia farming could generate seasonal employment, integrate with aquaculture and salt, and empower women's cooperatives.

Countries with Fast-Growing Aquaculture Sectors

- **Nigeria** harvest ~1 million tonnes per year of farmed catfish (2021), valued at ~USD 2.6 billion; the aquafeed market is >USD 500 million.
- **Madagascar**, **Tanzania**, and **Kenya** have shrimp farming sectors that are expanding rapidly, particularly in coastal regions where saline land is abundant and hatchery infrastructure is emerging. These countries are exploring export-oriented shrimp farming (for example, the new World Bank-financed NAMARET hatchery in Kenya), making them ideal for Artemia cyst production and integration into hatchery protocols.

These countries represent ideal targets for Artemia biomass farming as a local, affordable feed supplement for hatcheries and grow-out systems.

Investment Potential in Latin America

While Latin America is not a major player in the global Artemia sector, it holds strong potential for scale-up in select geographies. The region is characterized by a mix of saline geographies, growing aquaculture sectors, and established salt industries. A number of countries present promising entry points for Artemia cyst or biomass production, whether for domestic feed integration or strategic export.

- **Brazil's** northeast region, particularly Rio Grande do Norte, has large inland saline aquifers and a strong tilapia aquaculture sector. With over 800,000 tonnes of fish produced annually, Brazil offers a large domestic aquafeed market and growing demand for sustainable feed ingredients.
- **Peru** combines active marine shrimp production along its northern coast with extensive solar salt operations. While Artemia is currently imported, local cyst or biomass production could support domestic hatcheries.
- **Mexico** is one of the region's largest shrimp producers and has a well-developed hatchery network, particularly in Sonora and Sinaloa. Artemia cyst imports remain high, and coastal salt pans present a dual-use opportunity.
- **Ecuador's** shrimp exports are booming, and the country has a large ornamental fish sector supported by hatcheries and small-scale feed production. Artemia biomass could be integrated into broodstock and larval feeds.
- While **Chile's** aquaculture sector is dominated by salmon, there is growing interest in alternative live feeds for early-stage marine finfish. Artemia could play a niche role in larval rearing and experimental hatcheries, particularly if paired with nutrient enrichment or probiotic conditioning.

With diverse climatic zones, aquaculture ambitions, and existing saline infrastructure, Latin America offers a mosaic of Artemia development opportunities. Tailored entry models—whether biomass farming, cyst production, or integrated salt systems—can unlock value across national and regional value chains.

Investment Potential for the Middle East

The Middle East presents a high-potential region for Artemia scale-up due to its vast saline landscapes, large solar salt industries, growing aquaculture sectors, and strategic geographic positioning. While Artemia has historically been sourced from wild systems (notably in Iran), there is growing recognition that farmed Artemia could support both regional feed security and saline land valorization.

- **Iran** has historically been one of the largest wild Artemia producers globally, with Lake Urmia once yielding over 1,000 tonnes of cysts per year. However, due to ecological degradation and declining lake volume, wild production has dropped dramatically. Today, Iran produces up to 20 tonnes of Artemia biomass annually from pilot farming initiatives in saline ponds. Opportunities exist to develop commercial-scale Artemia production in inland saline zones like the Dasht-e Kavir and coastal plains near the Persian Gulf. Iran also imports Artemia cysts to meet hatchery needs, especially in its marine aquaculture expansion zones.
- **Saudi Arabia's** aquaculture production has grown from under 50,000 tonnes in 2016 to over 100,000 tonnes in 2023, with a government target of reaching 600,000 tonnes by 2030 under the Vision 2030 program. The country imports an estimated 60–100 tonnes of Artemia cysts annually for its shrimp hatcheries. With extensive salt pans in Jizan, Umluj, and Al Jubail, Saudi Arabia could scale Artemia farming alongside shrimp production. The Red Sea coastline offers natural brine conditions and infrastructure to pilot integrated Artemia-salt systems.
- **The United Arab** Emirates produces over 100,000 tonnes of salt annually, and its National Food Security Strategy encourages innovation in desert aquaculture and saline agriculture. The country has several ornamental aquaculture operations and R&D centers exploring high-value live feeds. Artemia biomass could be cultivated in salt pans around Abu Dhabi and Ras Al Khaimah, particularly for value-added feed products, broodstock conditioning, or human nutrition trials.

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CONCLUSION AND INVESTMENT ROAD MAP

Drawing on the synthesis of country cases, investment criteria, and market dynamics presented throughout the studies, this section offers a practical, forward-looking approach to Artemia investment. This roadmap outlines a strategy for catalyzing system-level transformation across value chains, in line with World Bank investment logic—prioritizing inclusivity, scalability, and climate resilience.

A Shift from Trials to Transformation

Artemia farming should not be seen as a stand-alone technical farming solution but as a lever to unlock broader impacts across aquaculture, feed systems, and saline land use. The investment opportunity lies in

- **De-risking saline landscapes** by repurposing underutilized assets (for example, solar salt farms, degraded coastal zones, and inland salt-affected areas);
- **Reducing feed import dependence** through biomass integration into hatchery and nursery systems;
- **Creating inclusive new employment** by layering Artemia onto artisanal salt farming systems and adding value and jobs to larger salt industry operations;

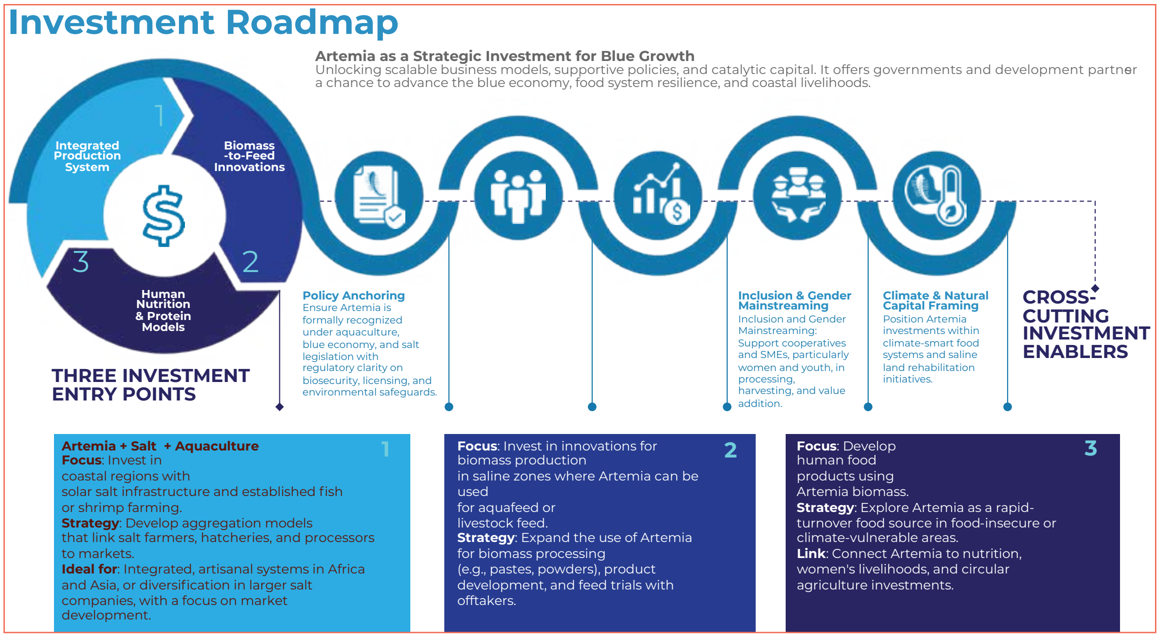
- **Driving blue economy growth** by embedding Artemia into aquaculture, feed, and food policy instruments and investments; and
- **Sustainable new aquabusinesses** that are profitable, creating new jobs, often in marginalized regions, though significantly dependent on market development and new applications in feed and human food.

Three Investment Entry Points

1. **Integrated Production System (Artemia + Salt + Aquaculture)**
    - Investing in coastal regions with solar salt infrastructure and existing fish/shrimp farming.
    - Investing in aggregation models and value-chain development that link salt farmers, hatcheries, and processors to markets.
    - Ideal for integrated, artisanal systems across Africa and Asia, or diversification in larger salt companies, with market development.
2. **Biomass-to-Feed Innovations**
    - Investing in innovations, market development, and biomass production for saline zones where Artemia can be grown for aquafeed or livestock feed.
    - Focusing on expanding use of Artemia for biomass processing, product development (for example, pastes and powders), and feed trials with offtakers.
3. **Nutritional Access Protein Models**
    - Using Artemia biomass to develop human food products and markets.
    - Exploring Artemia as a rapid-turnover food option in food-insecure, humanitarian relief, or climate-vulnerable contexts.
    - Linking Artemia with nutrition, women's livelihoods, and circular agriculture.

Cross-Cutting Investment Enablers

- **Policy anchoring**: Artemia must be formally recognized under aquaculture, blue economy, and/or salt legislation. Regulatory clarity on biosecurity, licensing, and environmental safeguards is essential.
- **Anchor partners**: Investments should be designed around committed offtakers (for example, hatcheries and feed mills) and implementation partners (for example, local governments, cooperatives, and NGOs).
- **Blended finance and risk sharing**: Use public finance to crowd-in private capital through guarantees, concessional loans, or challenge funds.
- **Inclusion and gender mainstreaming**: Support cooperatives and SMEs—especially women and youth—in processing, harvesting, and value addition.
- **Climate and natural capital framing**: Position Artemia investments within climate-smart food systems and saline land rehabilitation.



Strategic Sequencing for Investment

Opportunities for investment in biomass and cyst production for aquaculture and broader application in animal feed and human food markets should be further assessed at country or business levels taking a step-wise approach. The following are some key steps for investment:

1. **Scoping and stakeholder engagement:** Identify priority countries, national champions, and potential co-investors, while mapping market opportunities and establishing memorandums of understanding (MoUs).
2. **Platform and model design:** Align business models with local systems and policies through feasibility assessments and the development of tailored investment proposals.
3. **Capital structuring:** Mobilize blended finance, including public-private partnerships (PPPs), and define roles to coordinate grants, loans, and investment terms.
4. **Inclusive rollout:** Launch initiatives with integrated technical support, capacity building, and digital tools, ensuring creation of jobs, promotion of gender equity, and alignment with climate objectives.
5. **Policy and scale:** Embed Artemia into long-term national investment plans to enable strategic adoption and support replication and scale-up across regions.

This road map reframes Artemia not just as a biological input but as a strategic investment platform—one that can be scaled through inclusive business models, policy integration, and catalytic capital. For governments and development partners, the opportunity is to turn Artemia into a vehicle for advancing the blue economy, food system resilience, and coastal livelihood transformation.

Strategic Sequencing for Investment

Phased Approach to Assessing Artemia Investment Opportunities

PHASE	OBJECTIVE	OUTPUTS
1 Scoping & Stakeholder Engagement	Identify priority countries and national champions/partners, and potential co-investors	Country opportunities, site suitability mapping, economic and market analysis, partner MoUs and investment concepts
Platform and Model Design	Catalyse national businesses to design models and opportunities aligned with local systems and policy	Feasibility assessments, investment proposals
Capital Structuring	Mobilize blended finance (eg, PPP) and define roles	Investment term sheets, grants + loans alignment
Inclusive Rollout	Launch with embedded technical assistance, capacity support, and digital tools	Jobs, gender, climate, targets
Policy and Scale	Embed Artemia into long-term country investment plans	Strategy adoption, replication funding

Next Steps

The next steps are to conduct a dissemination and awareness-raising activity of the Artemia aquabusiness study findings and investment opportunities, involving country scoping, workshops, engagement with innovators and research institutes, and private sector networking with solar salt works and related feed companies.

- **Awareness raising of Artemia investment opportunity** through online and in-person meetings, such as among World Bank and International Finance Corporation (IFC) teams and clients, stimulating investment in new and existing projects among the aquaculture industry and investors, particularly larger events focused on Africa, Asia, and Latin America (for example, World Aquaculture Society, Agri-Food Innovation Summit).
- **Country actions** through country visits and investment planning to assess opportunities and prepare investment strategy and plans with national partners, actively seeking to replicate biomass, solar salt, artisanal, and cyst models showcased in the study, as applied to national priorities and opportunities.
- **Business catalyzer** through convening and networking activities with innovative companies and forward-looking salt businesses to design Artemia investments, including brine shrimp as a novel aquaculture and animal feed ingredient and for human food applications.
- **Online presence of communications products,** including reports, inventory, event videos, and synthesis products: Through PROBLUE and IAAC web sites, events, and active promotion through social media, show World Bank leadership in Artemia aquabusiness investment promotion.

REFERENCES

Anh, N. T. N., N. V. Hoa, G. Van Stappen, and P. Sorgeloos. 2009. "Effect of partial harvesting strategies on Artemia biomass production in Vietnamese salt works." Aquaculture Research 40 (16): 1853–1861

Bwala, R. L., K. Salie, and G. Van Stappen. 2018. "Ovoviviparously Produced Artemia Nauplii are a Suitable Live Food Source for the Larvae of the African Catfish (Clarias gariepinus)." Aquaculture Research 49 (10): 3319–3328.

FAO. 2023. *Report of the Twelfth Session of the Sub-Committee on Aquaculture, Hermonsillo, Mexico, 16-19 May 2023*. Available at: https://www.fao.org/3/cc7093t/cc7093t.pdf (Accessed: December 6, 2024).

FAO. 2024. "Artemia: Life Cycle and Morphology." YouTube - FAO. Available at: https://www.youtube.com/watch?v=GgN-E8-LMCY%20 (Accessed: December 4, 2024).

FAO. 2024. *Manual on Artemia production and use.* Edited by G. van Stappen, P. Sorgeloos, and G. Rombaut. (eds). FAO Fisheries and Aquaculture Technical Papers No. 702. Available at: https://doi.org/https://doi.org/10.4060/cd0313en.

Gajardo, G. 2024. "World Artemia Biodiversity." YouTube - NACA. Available at: https://youtu.be/fm-SWTk_GIM?si=jZjy3p3m7upk-BN7 (Accessed: December 5, 2024).

Hoa, N. V., L. V. Thong, and P. Sorgeloos. 2020. "State of the Art of Brine Shrimp Artemia Production in Artisanal Saltworks in the Mekong Delta, Viet Nam." *World Aquaculture Magazine*, September. Available at: https://www.was.org/Magazine/Vol/51/3 (Accessed: December 4, 2024).

Hoa, N. V. and P. Sorgeloos. 2020. "Human Food Trials with Artemia in Viet Nam." In *Proceedings of the International Workshop on Artemia: Current Status and Future Perspectives*, edited by G. Van Stappen and B. Gunther, 45–52. Ghent: University of Ghent.

Lavens, P. and P. Sorgeloos. 2000 "The History, Present Status and Prospects of the Availability of Artemia Cysts for Aquaculture." *Aquaculture* 181 (3–4): 397–403. Available at: https://doi.org/10.1016/S0044-8486(99)00233-1.

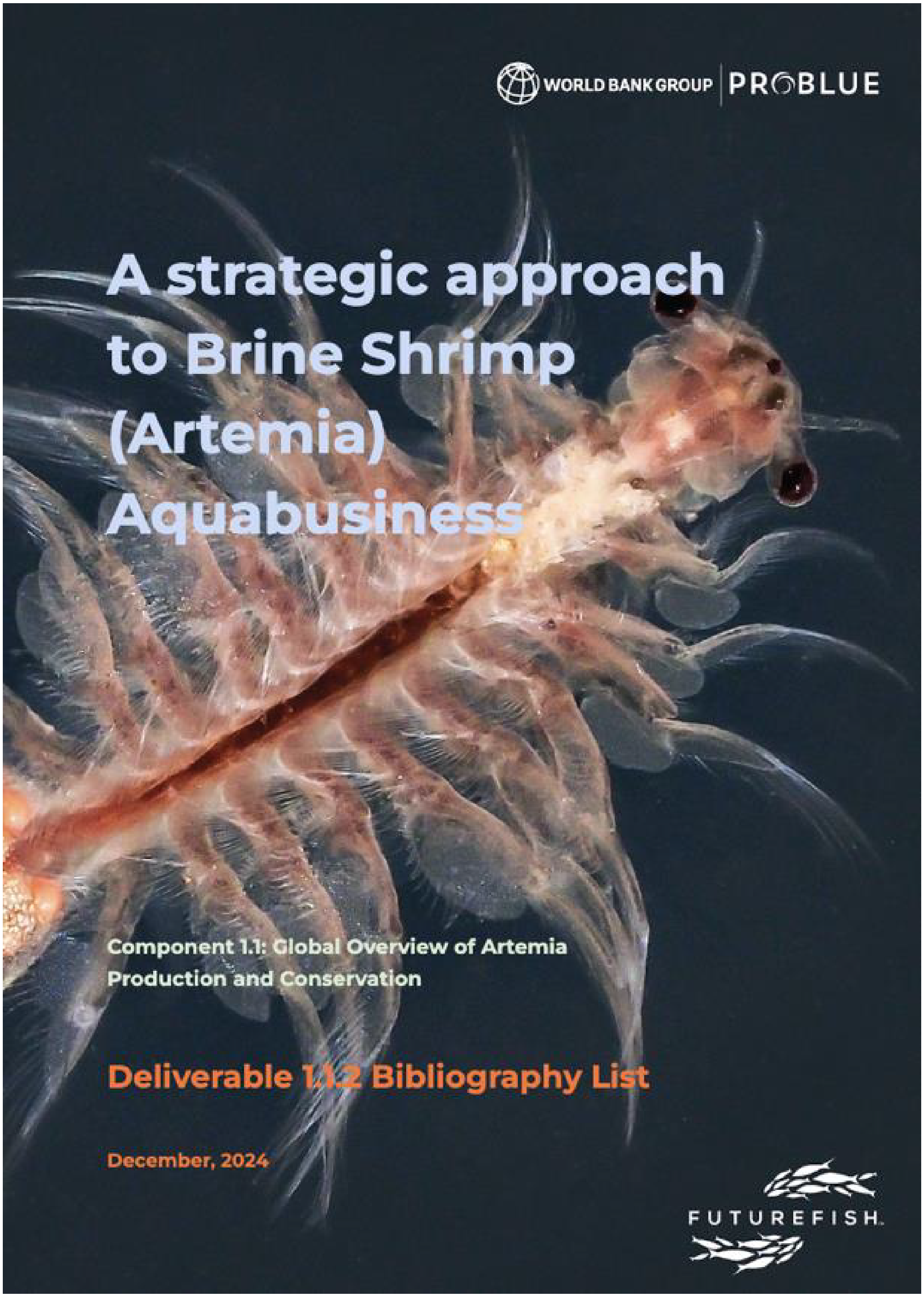
Rahman, M., V. H. Nguyen, and P. Sorgeloos. 2022. *Handbook for Artemia Pond Culture in Bangladesh*. WorldFish. Available at: https://hdl.handle.net/20.500.12348/5374 (Accessed: December 4, 2024).

Ronsivalli, P. C. and K. L. Simpson. 1987. "The Brine Shrimp Artemia as a Protein Source for Humans." In Artemia Research and its Applications. Vol. 3. Ecology, Culturing, Use in Aquaculture, edited by P. Sorgeloos, D. A. Bengtson, W. Decleir, and E. Jaspers, 503–514. Wetteren, Belgium: Universa Press.

Syeda, S. 2023. *Artemia Biomass Recipes as Human Food*. Bayan Lepas, Malaysia: WorldFish. Available at: https://hdl.handle.net/20.500.12348/5609 (Accessed: December 6, 2024).

Van Stappen, G. et al. (2020) "Review on Integrated Production of the Brine Shrimp *Artemia* in Solar Salt Ponds." *Reviews in Aquaculture* 12 (2): 1054–1071. Available at: https://doi.org/10.1111/raq.12371.

A complete bibliography can be found in this report



ANNEX A: BUSINESS MODEL DESCRIPTIONS

These country business models as presented in infographics above.

Name of Business Model	Bangladesh Integrated Salt-Artemia-Aquaculture Farming
Category	**Details**
Diversified Income Opportunities	Artemia cysts, biomass, salt production, brine sales, shrimp and crab hatchery integration. ‘Off-season’ culture of other aquatic species, such as fish and shrimp, provides additional income
Description	Seasonal Artemia biomass and cyst farming integrated with salt production, and aquaculture, providing Artemia and other aquatic products for market into shrimp and crab hatcheries and for human consumption
Total Production per Cycle	Artemia Cysts: ~17 kg/ha per cycle (120 kg total over 7 ha in 4 years) Artemia Biomass: 1.3–1.4 tons/ha per cycle Multiple aquaculture products: tilapia, shrimp
Cycle Time	January–May (dry season) Aquaculture products in rainy season
Tons per ha per Cycle	Cysts: ~17 kg/ha Biomass: 1.3–1.4 tons/ha
Cost per kg	Around USD 36 per kg for cysts and USD 1.4 per kg for biomass
Cost per ha per Cycle	Pond construction, land lease, fertilization, brine preparation, casual labor (USD 2,500 per ha per season for both)
Selling Price ($/kg)	Cysts: USD 50–100 per kg Live biomass: $4.0 - $5.0/kg
Revenue per ha	Estimated USD 8,000 per ha per season
Profit Margin	60-70%
Investment Cost & ROI	1–2 workers per farm (total 108 laborers)
Employment per ha	54 farmers in 2024, producing 6.7 MT of biomass in 5.0 ha
Average farmer income	USD 740 per farmer per season (from total USD 40,000 revenue split among 54 farmers)
Women in Workforce	Involved in post-harvest processing and sorting (20%)
Technology Needed	Nets, fertilization systems, seawater pumps, and brine evaporation ponds
Environmental Conditions	Salinity: 70-90 g/L, Seasonal production limited by monsoon rains

Name of Business Model	Bangladesh Integrated Salt-Artemia-Aquaculture Farming
Main Markets	Shrimp, crab, and finfish hatcheries. Tilapia and other aquaculture products into domestic food markets
Domestic vs. Export Market	100% sold domestically to hatcheries and nurseries
Untapped Potential	Potential for expanding Artemia biomass processing for frozen feed, integration with shrimp and crab aquaculture, and human food applications

Name of Business Model	China Artemia Solar Saltworks Model
Category	**Details**
Diversified Income Opportunities	Artemia cysts, biomass, salt production, brine sales, shrimp aquaculture integration
Summary	Large-scale Artemia production integrated into massive solar saltworks, where cysts and biomass are produced seasonally alongside salt.
Total Production per Cycle	Cysts: 500–600 tons annually (wet weight) Biomass: 200,000–300,000 tonnes annually
Cycle Time	April to November (seasonal production)
Tons per ha per Cycle	Cysts: Produced in large salt ponds (30–60 ha per pond) Biomass: High-yield, large-scale collection
Production Cost per kg	USD 0.30 per kg for biomass
Cost per ha per Cycle	USD 5,000 per ha per year (for salt and cysts) - Fertilization (organic: chicken manure, inorganic: urea, DAP), labor, boats, pumps, power costs
Selling Price ($/kg)	Cysts: Premium quality at over USD 100 per kg , 150% higher price than inland cysts Biomass: USD 1.5 per kg
Revenue per ha	USD 6,000–30,000 but artemia biomass treated like by-product of salt production, and also used within vertically integrated hatchery
Profit Margin	30–50%; stable due to high demand; cysts sold at a premium due to better hatchability and nutrition
Investment Cost & ROI	Large-scale investment with infrastructure needs (boats, pumps, PVC pipes), but high return due to scale
Employment per ha	Manual labor-intensive due to pond size; most workers are men ages 40–60
Total Jobs Created	Bohai Bay saltworks employ hundreds in seasonal Artemia harvesting
Women in Workforce	Low participation of women (10% in labor, very few in leadership positions)
Technology Needed	Boats, pumps, PVC pipes, biomass harvesters, seed stock (once per season)
Environmental Conditions	Salinity: 80–150 g/L Ponds: 30–60 ha per unit, 80–150 cm deep High eutrophication supports Artemia and algae growth
Main Markets & Consumers	*Macrobrachium* and shrimp hatcheries, domestic aquaculture, export markets
Domestic vs. Export Market	90% of cysts sold domestically (Zhejiang province); 10% exported (Southeast Asia, Korea)
Untapped Potential	China still imports 800–1,000 tons of Artemia cysts per year, mostly from Russia, Kazakhstan, and the United States; there is significant potential for expanding domestic cyst production to reduce imports

Name of Business Model	Thailand Artemia Biomass Farming
Category	**Details**
Diversified Income Opportunities	Artemia biomass, salt production, brine sales, shrimp and marine hatchery integration
System Summary	Year-round Artemia biomass farming in modified salt ponds, supplying local hatcheries and ornamental fish markets.
Total Production per Cycle	Biomass: 2.25–4.5 tons per ha per month (semi-intensive)
Cycle Time	Year-round operation possible, with peak production in dry season
Tons per ha per Cycle	Biomass: 2–4 tons per ha per cycle
Production Cost per kg	USD 0.15–0.50 per kg
Cost per ha per Cycle	Labor (1–2 workers per ha), fertilization, water management
Selling Price ($/kg)	Live biomass: USD 1.75–1.78 per kg; Frozen biomass: USD 1.50–1.63 per kg
Revenue per ha	USD 3,500–9,600
Profit Margin	Annual revenue: Up to USD 27,000–38,000 per farm Profit until end-user can exceed 50%, with processors taking 30–40%
Investment Cost & ROI	Low investment cost and payback period of 1–2 years
Employment per ha	1–2 workers per ha
Total Jobs Created	15–20 commercial farms, 45 ha under production, 340 tons biomass (2020–2021)
Women in Workforce	Women involved in post-harvest processing, sorting, and packing
Technology Needed	Buckets, nets, fertilization systems, aeration, IoT-based water quality monitoring
Environmental Conditions	Salinity: 80–150 g/L, high evaporation zones near salt pans
Main Markets	Shrimp, crab, marine finfish hatcheries, ornamental fish markets but huge potential across many species and for terrestrial animal feeds
Domestic vs. Export Market	75% sold domestically to hatcheries, 25% exported (mainly frozen biomass)
Untapped Potential	Thailand does not produce cysts; 482 tons of Artemia cysts were imported in 2020, mostly from China, Russia, Uzbekistan, and Kazakhstan. Potential for integrating Artemia cyst production in salt farms.

Name of Business Model	Viet Nam Artemia Salt Pond Farming
Category	**Details**
Diversified Income Opportunities	Artemia cysts, biomass, salt production, and brine sales
Description	Seasonal Artemia farming in modified salt ponds during the dry season, producing high-value cysts and biomass with strong domestic and export market potential for cysts.
Total Production per Cycle	Cysts: 50–70 kg/ha (wet weight), with potential improvement to 100–150 kg/ha Biomass: 4–5 tons/ha per cycle
Cycle Time	4–5 months (dry season), or all year in more intensive systems with deeper ponds and water availability
Tons per ha per Cycle	Cysts: 50–70 kg (150–200 kg in intensive systems) Biomass: 4–5 tons
Production cost per kg	USD 15–20 per kg (raw cysts, wet weight) selling by farmers

Name of Business Model	Viet Nam Artemia Salt Pond Farming
Cost per ha per cycle	Stocking (inoculum) and feed (~30% each) Labor: 2–3 people per ha
Selling Price ($/kg)	Cysts: USD 200 per kg (high-quality Viet Nam cysts) Imports (cheaper cysts from the US, China, Russia): USD 50–100 per kg
Revenue per ha	USD 3,000 per ha but up to USD 7,000 per ha in more intensive systems Biomass and brine: Additional revenue streams
Profit Margin	Profit until end-user can be more than 60%, but in Viet Nam gets sold to processor at around 30–50% profit
Investment Cost & ROI	Potentially high cost but could pay back after 1–2 years
Employment per ha	2–3 workers per ha
Total Jobs Created	1,000–2,000 jobs (for more seasonal systems)
Women in Workforce	~20% in Viet Nam at production level but women mostly involved at processing level
Technology Needed	Buckets, rakes, pipes, scoop net, brine transport systems but can require higher technical needs such as cyst processing set (including separation funnel, centrifuge, fluidized bed dryer, sieving machine, and canning equipment)
Environmental Conditions	Salinity: 80 g/L at Artemia stocking Temperature: Suitable for Artemia growth in dry season Brine sales: 1 m^3 brine = USD 1–2 Seawater quality improvement: 1 m^3 brine + 4 m^3 freshwater = pathogen-free seawater for hatcheries
Main Markets	Crab, marine fish, shrimp hatcheries
Domestic vs. Export Market	In Viet Nam, about 50% cysts are sold domestically, 50% exported
Untapped Potential	Viet Nam hatcheries prefer cheaper imported cysts (~USD 50–100 per kg versus Viet Nam's USD 200 per kg) but local crab hatcheries require the higher quality cysts. With optimized costs, Viet Nam Artemia cysts could expand its market share in domestic and export markets

Name of Business Model	Kenya Artemia cysts and biomass farming
Category	**Details**
Diversified Income Opportunities	Artemia biomass, Artemia cysts, salt production, marine finfish and shellfish, planting mangrove seedlings and trees in coastal ecosystems
Description	Integrated salt-Artemia aquaculture production, combining salt production and, in some cases, fish farming for added income
Total Production per Cycle	Cyst production is 3,031 g per ha per month in a semi-intensive system Artemia biomass production is 3,797 g per ha per month in a semi-intensive system. Though it has reached 33 kg and 250 kg/ha, respectively.
Cycle Time	9 months per year (Oct–June) operation possible, with peak cyst production in the rainy season while the biomass declines with the onset of the rainy season Fish production season is expected to take place within the three months when salinities drop, during the cold season between July and September

Name of Business Model	Kenya Artemia cysts and biomass farming
Productivity per ha	Cysts: minimum of ~3 kg/ha per month to 33 kg/ha per season Biomass: minimum of ~3.8 kg/ha per month and 250 kg/ha per season
Production costs per kg	Cysts: USD 7 per kg. Biomass: USD 2 per kg
Cost per ha per cycle	Labor (2 workers per farm), water management, pond management, cyst inoculation, cyst and biomass collection/harvesting – 1 worker per day is paid Kshs 250, equivalent of USD 2
Selling Price ($/kg)	USD 62.5 for cysts USD 4–5 per kg for biomass
Revenue per ha	7 commercial farms with average 2 ha each, and 9 small-scale with average 0.5 ha each; around USD 590 per ha for biomass or USD 1,700 for cysts
Profit Margin	Margin on cysts around 89%, and 56% for biomass
Investment Cost & ROI	Low investment cost and payback period of 2 years
Total Jobs Created	9 artisanal farms (1 is group owned while the other 8 are owned by individuals) of about 50 ha per farm and 7 commercial solar saltworks of about 3,000–6,000 ha (but no artemia)
Women in Workforce	Around 40% of women involved in pond construction and pond management
Technology Needed	Salt ponds, Artemia cysts for inoculation, hatching equipment - aerators, buckets, pipes and so on, seawater pumps, water quality monitoring, raking equipment, harvesting buckets
Environmental Conditions	Salinity: 80–150 g/L; high temperatures hence high evaporation rates; water increases in salinity as it moves from one pond to another through gravity as a result of evaporation
Customers & Markets	Shrimp, crab, marine finfish, ornamental hatcheries, ornamental fish markets, students, researchers, catfish fish farmers, commercial and artisanal salt farmers
Domestic vs. Export Market	100% is sold in the domestic market, with potential to grow and diversify
Untapped Potential	Kenya Artemia cysts and biomass farming, associated with market development.

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