

INNOVATION IN ARID ENVIRONMENTS: BUILDING RESILIENT AND SUSTAINABLE AQUACULTURE IN SAUDI ARABIA

By Benjamin C Young, Saif Algethami, Anwer Abed Alazwari, Faris Alghamdi, and Ali AL Shaikhi

Despite limited natural water resources and a relatively late start, Saudi Arabia's aquaculture sector has developed steadily over the past two decades. This growth has been underpinned by strategic government policies, robust disease control, species adaptation, and industry guidance aimed at structural transformation. However, to ensure long-term environmental and industrial sustainability, it remains essential to scale up local hatchery production further, strengthen biosecurity frameworks, adapt farming systems to local species, and cultivate specialised local talent.



Farmed products certified by the Saudi national aquaculture certification and labeling program (SAMAQ), which guarantees premium quality and food safety.

In contrast to the scarcity of freshwater and arable land, Saudi Arabia has an extensive coastline of 7 572 km, extending from the Red Sea in the west to the Arabian Gulf in the east. Approximately 2 400 km of this undeveloped coastline presents significant potential for aquaculture expansion. Furthermore, these waters host a diverse array of indigenous marine finfish with high commercial potential, including the snubnose pompano (*Trachinotus blochii*), sobaity seabream (*Sparidentex hasta*), and red mangrove snapper (*Lutjanus argentimaculatus*).

Saudi Arabia's aquaculture journey began in the 1970s, initially mirroring the trajectory of many developing nations by focusing on freshwater species, primarily tilapia (*Oreochromis niloticus*). However, by the mid-1990s, a strategic shift driven by policy planning, market demand, and favourable marine conditions catalysed the rise of shrimp farming, which eventually surpassed freshwater production.

The shrimp sector flourished until 2010, when an outbreak of White Spot Syndrome Virus (WSSV) decimated the then-primary species, the Indian prawn (*Fenneropenaeus indicus*). In a resilient response, the industry transitioned to farming Specific Pathogen-Free (SPF) Pacific white shrimp (*Litopenaeus vannamei*), which has since dominated the sector, accounting for over 70% of total mariculture output.

Aquaculture production in Saudi Arabia increased from 6 004 tonnes in 2000 to 139 949 tonnes in 2023; this annual growth rate of 14.7 percent is higher than the sub-regional, regional, and world averages. In 2023, Saudi Arabia's total aquaculture production reached approximately 139 949 tonnes, with mariculture (shrimp and marine finfish) contributing 92 491 tonnes. Key mariculture species, including Asian seabass (*Lates*

calcarifer), gilthead bream (*Sparus aurata*), Sabaki tilapia (*Oreochromis spilurus*), and sobaity seabream, contributed over 30 000 tonnes collectively. This growth has been particularly evident in the Arabian Gulf region through the establishment of localised hatcheries and integrated farms for shrimp, seabass, sea bream and groupers (*Epinephelus* spp.).

Inland aquaculture remains a pillar of national food security, with tilapia production reaching approximately 45 200 tonnes in 2023, representing nearly 32% of total national output. North African catfish (*Clarias gariepinus*) follows as the second-largest freshwater species at 1 230 tonnes. These inland operations remain essential for rural development and stabilising the domestic food supply.

Aquaculture challenges in Saudi Arabia

Environmental and resource constraints

The Saudi aquaculture industry faces significant hurdles, including limited natural resources, a scarcity of high-quality broodstock, inadequate site selection, a shortage of skilled personnel, and biosecurity threats. While Saudi Arabia's interior is often perceived as a barren desert, the reality is that arable land accounts for only 1.8% of the country's total area. The scarcity of surface and groundwater further intensifies this challenge. Currently, the agricultural sector consumes over 80% of the nation's water (primarily from deep aquifers) severely constraining aquaculture expansion. Consequently, tilapia farms are concentrated in Al-Qassim and the regions surrounding Riyadh, where freshwater is more readily available. As illustrated in Figure 1, production volume and farm density decrease progressively toward coastal areas.

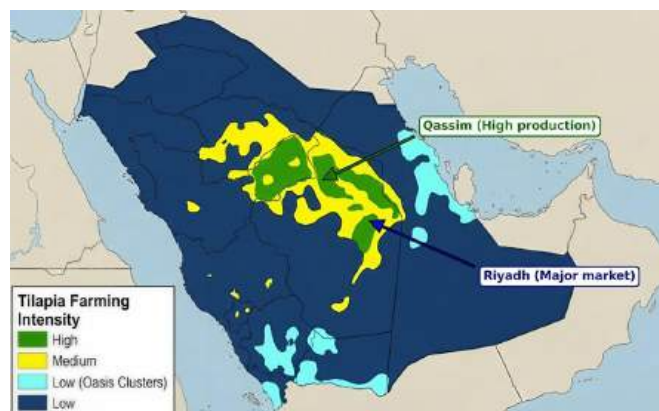


Figure 1. Major tilapia farming hubs in Saudi Arabia

Salinity and operational barriers

Environmental constraints extend to the coastline, where seawater salinity typically ranges from 42‰ to 45‰, which is significantly higher than the ideal larviculture range of 10‰ to 33.5‰. High water temperatures, fluctuating between 17.5°C and 35°C, further limit species suitability and operational feasibility (Figure 2). Beyond these natural factors, strict government regulations on well drilling and groundwater extraction make freshwater a high-cost component. The combined burden of hypersalinity and water scarcity remains a primary bottleneck for the industry.



Figure 2. Water temperature range of aquaculture regions in Saudi Arabia.

Structural and management challenges

The industry structure also presents unique challenges. Unlike the mariculture sector, which is dominated by a few mega-companies, the freshwater sector consists of approximately 350 small-scale, scattered farms. Before the 2010s, the Ministry of Environment, Water, and Agriculture (MEWA) struggled to monitor these operations due to the absence of standardised guidance and the fragmented distribution of facilities. Ineffective farm management often resulted in inconsistent product quality, unreliable production estimates, and compromised disease prevention measures.

Seedstock and seed dependency

Furthermore, Saudi Arabia's marine finfish sector remains heavily dependent on imports of fingerlings from Bahrain, Türkiye, and Mediterranean countries, thereby limiting species diversification and product development. This reliance on imported eggs and larvae stems from a localised failure to produce sufficient high-quality juveniles. Even in the tilapia sector, the quality and quantity of broodstock remain insufficient for most local hatcheries, leading to a persistent shortage of qualified juveniles on domestic farms.

Human capital and infrastructure

Due to the industry's relatively short history, there has been a chronic shortage of experienced farm management personnel. In the 1990s and 2000s, recruiting and training local talent was a significant challenge, exacerbated by a lack of specialised vocational training organisations. Coupled with the high capital expenditure required for production facilities in such extreme environments, these factors have historically hindered the sector's competitive growth.

Strategic frameworks for resilience and sustainable growth

National policy integration

Since 2018, the Ministry of Environment, Water and Agriculture (MEWA) has accelerated aquaculture development through Saudi Arabia's national transformation programs, specifically Vision 2030 and the Sustainable Rural Agricultural Development Program (REEF). These initiatives are designed to establish robust food security and sustainability strategies across the environment and agriculture sectors. Under these frameworks, MEWA has successfully integrated governmental, private, and academic resources to catalyse improvements in technology transfer, farm management, workforce training, disease prevention, and market access.

Water management and circularity

To safeguard finite groundwater resources, MEWA has implemented a dual approach: rigorous monitoring and pumping quotas coupled with the active promotion of Integrated Agri-Aquaculture (IAA) and aquaponic systems. Innovative initiatives, such as the cultivation of *Azolla* within aquaculture ponds as organic fertiliser and protein-rich feed, are also underway. Consequently, IAA practices have flourished in Al-Qassim, Al-Ahsa and Riyadh. In these clusters, farmers utilise deep groundwater for tilapia rearing, subsequently repurposing the nutrient-rich effluent for crop irrigation. This synergy optimises water-use efficiency and enhances agricultural circularity.



The Ministry of Environment, Water and Agriculture MEWA is actively promoting Integrated Agri-Aquaculture (IAA) and aquaponic systems.

Regional models of sustainability

These regions represent two distinct paths toward sustainability: Al-Ahsa exemplifies the 'Ecological Resilience' model, rooted in historical oasis management and natural water discharge; conversely, Al-Qassim embodies the 'Technological Optimization' model, demonstrating how modern IAA practices, supported by stringent regulations, can mitigate

the depletion of fossil aquifers. Together, these cases provide a comprehensive overview of the strategic adaptations within the Saudi aquaculture sector.

Marine innovation and socio-economic growth

Regarding coastal operations, MEWA is actively encouraging the adoption of Recirculating Aquaculture Systems (RAS) to maximise water efficiency. The Ministry is also designating specialised aquaculture zones and diversifying cultivated species to streamline production. Along the coastline, new initiatives for seaweed and algae cultivation are being implemented to stimulate regional development. These strategic efforts aim to drive economic growth in coastal communities, fostering local engagement and creating long-term, sustainable employment opportunities.



Young Saudis, including women, are actively involved in seaweed production.

Seedstock security and native species commercialisation

The stability of fry sources is fundamental to sustainable development; therefore, prioritising broodstock management is imperative. To address the current shortage of local supply, MEWA is prioritising the expansion of hatchery capacity. While Saudi Arabia has achieved commercial success with white shrimp, tilapia, Asian seabass, and gilthead bream, total output remains influenced by inherent environmental limitations,

necessitating imports to meet high domestic demand. To mitigate disease risks and climate vulnerability, MEWA is pursuing the commercialisation of native species, such as snubnose pompano and sobaity seabream, to strengthen the sector’s long-term resilience.



A fish hatchery in Saudi Arabia.

Recent research provides critical scientific evidence to facilitate this scale-up: for instance, snubnose pompano exhibits higher survival rates at a salinity of 39‰ compared to 42‰, while sobaity seabream maintains comparable growth rates at 28°C as at 24°C. These findings are vital for streamlining production workflows and reducing operational costs in extreme arid environments.

Knowledge transfer and biosecurity protocols

MEWA collaborates with local universities, international organisations, and national research centres to improve technology transfer. Through practical workshops and technical training, local professionals are enhancing their expertise to support the ongoing development of the national aquaculture sector. These centres offer technical assistance, consultation, and high-quality fry to farmers to elevate the standards of local operations. On the biosecurity front, MEWA regularly convenes industry leaders for seminars and maintains a rigorous national tracking system for aquatic diseases. Stringent regulations govern the import of live fish, restricting permits to licensed operators to prevent pathogen outbreaks. Furthermore, the Ministry provides farmers with comprehensive biosecurity manuals and conducts regular farm monitoring to ensure compliance.



Capacity-building and technical training for national officials.

Market development and SAMAQ certification

Beyond production, MEWA aims to increase annual per capita seafood consumption from the current 9–12 kg to 13 kg by 2030, aligning closer to the global average (20.7 kg). To achieve this, the Ministry organises promotional activities and assists operators in obtaining international certifications such as HACCP, ISO, and Best Aquaculture Practices (BAP). Central to this strategy is the Saudi national aquaculture certification and labeling program (SAMAQ) which guarantees premium quality and food safety. By implementing these rigorous frameworks, the government enhances the competitiveness of local producers, facilitating the expansion of Saudi aquaculture products into international export markets.

Empowering a new workforce: the evolving role of women in aquaculture

The transformation of Saudi Arabia’s aquaculture sector is not only a technical achievement but also a landmark for social progress. Historically, women’s participation in this industry was primarily confined to administrative or marketing roles, owing to social norms and limited access to field-based training. However, under the framework of Vision 2030 and the REEF initiative, a profound shift is occurring. Women are increasingly transitioning from “the office to the field,” becoming essential contributors to the operational value chain.

Recent field projects led by MEWA and the Food and Agriculture Organization of the United Nations (FAO) have demonstrated that Saudi women can excel in specialised segments such as seaweed farming and

advanced postharvest processing. In regions like Jeddah and the Farasan Islands, women are now actively engaged in seaweed cultivation, including managing raft systems, tying seedlings, and overseeing postharvest drying. Simultaneously, training programs have empowered local women to modernise traditional artisanal practices, such as tuna canning and salt-drying, with a focus on hygiene, branding, and value recovery. These efforts do more than create jobs; they foster rural livelihoods, enhance community resilience, and ensure that the future of Saudi aquaculture is both inclusive and sustainable. However, sustained participation will depend on continued access to field-based training, safe working environments, and clear career pathways.

Beyond the farm: impact on society and future vision

The transformation of Saudi Arabia's aquaculture sector is not merely a technical achievement; it is a vital contributor to the country's socio-economic fabric. By reducing reliance on imported seafood, which currently fills the gap in domestic demand, the initiatives led by MEWA ensure that fresher, higher-quality fish reach the local dinner table faster and more sustainably.

A key highlight for the general public is the SAMAQ certification, which serves as a "quality seal". For everyday consumers, this label provides peace of mind, ensuring the fish they buy is raised to the highest international standards for food safety and environmental care. Furthermore, the industry's expansion is opening new opportunities for the national workforce. We are seeing a new generation of Saudi technicians, researchers, and entrepreneurs, including an increasing number of women, taking lead roles in seaweed production and high-tech farm management.

Looking ahead, the vision is to turn the desert's challenges into a global advantage. As technology continues to evolve, Saudi Arabia is positioning itself as a pioneer in "arid-region aquaculture". This means the innovations developed here, such as fish farming with minimal water and adapting species to high temperatures, could eventually be exported to help other dry regions worldwide achieve food security. In this way, a fish farm in the middle of the desert becomes more than just a source of food; it becomes a beacon of innovation for a changing planet.

Conclusion

The evolution of Saudi Arabia's aquaculture sector from its freshwater origins in the 1970s to a technologically advanced mariculture industry today is a testament to a long-term commitment to food security and economic diversification. However, as this review highlights, the path to a truly resilient and sustainable industry is paved with challenges, ranging from extreme environmental hypersalinity and thermal stress to a historical reliance on imported seedstock.

To achieve the ambitious goals set out in Vision 2030, the sector must now move beyond policy-driven demonstration projects. The transition to a fully integrated, commercially viable ecosystem is no longer optional; it is essential.

This requires a steadfast commitment to three strategic pillars:

- **Technological localisation:** Expanding domestic hatchery capacity and commercialising native species such as the snubnose pompano (*Trachinotus blochii*) and sobaity seabream (*Sparidentex hasta*), to reduce external dependencies and bolster biosecurity.
- **Environmental stewardship:** Scaling up circular models like Integrated Agri-Aquaculture (IAA) and Recirculating Aquaculture Systems (RAS) to harmonise production with the country's precious and limited water resources.
- **Human capital empowerment:** Bridging the technical gap through sustained international cooperation (such as the FAO partnership) and specialised vocational training (such as the Taiwan/CDF partnership) to equip a new generation of Saudi aquaculture professionals.
- By synergising scientific research with robust policy frameworks and international expertise, Saudi Arabia is not only securing its own food future but is also establishing a global benchmark for aquaculture innovation in arid regions. Ultimately, the successful maturation of this industry will transform environmental constraints into competitive advantages, ensuring that the national economy remains a resilient pillar of its heritage and future prosperity. 🌱

Acknowledgments

The authors express their gratitude to the Ministry of Environment, Water, and Agriculture, and the Food and Agriculture Organization of the United Nations for providing photos and materials.



Dr Benjamin C Young is a Senior Aquaculture Consultant for the Ministry of Environment, Water and Agriculture (MEWA) in Saudi Arabia. He also serves as a Technical Consultant for the Taiwan International Cooperation and Development Fund (Taiwan/CDF).



Mr Saif Algethami is the Director of the Aquatic Animal Health Department at the Ministry of Environment, Water and Agriculture, Saudi Arabia.



Mr Anwer Abed Alazwari is Director of Aquaculture Development Department at the Ministry of Environment, Water and Agriculture, Saudi Arabia.



Mr Faris Alghamdi is General Manager of Health and Fisheries Services at the Ministry of Environment, Water and Agriculture, Saudi Arabia.



Dr Ali Al-Shaikhi is the Assistant Deputy Minister for Livestock and Fisheries at the Ministry of Environment, Water and Agriculture, Saudi Arabia. The Ministry's mission is to drive sustainable aquaculture development, ensure animal health integrity, and empower the national workforce through strategic capacity-building within international cooperation frameworks.