

3 Results

3.1 Aquaculture challenges and opportunities in Singapore and global contexts

According to Funge-Smith and Phillips (2001), there are four types of aquaculture systems (Table 1). Singapore uses water-based systems, traditional and modern coastal net-cage farms and close-containment floating farms, and land-based systems, including tank-based culture, open-pond methods and indoor multi-tier systems (World Aquaculture Society, 2020; Singapore Food Agency, 2022a).

Table 1 Four types of Aquaculture systems

No.	Aquaculture system
1	Water-based systems in cages and pens, found in inshore and offshore settings.
2	Land-based systems: rain-fed ponds, irrigated channels, tanks and flow-through systems.
3	Recirculating aquaculture systems (RAS): enclosed systems and open pond-based recirculation.
4	Integrated farming systems: livestock-fish and combined agriculture-fish systems in farms and irrigation ponds.

Since the pandemic, the island nation has adopted a “30-by-30” target to achieve food security by producing 30% of its nutritional needs by 2030. The two types of aquaculture system used in Singapore are offshore and onshore farming (World Aquaculture Society, 2020). Singapore’s aquaculture industry comprises 110 licensed land- and sea-based fish farms and currently supplies about 10 percent of local fish consumption (Singapore Food Agency, 2022b). Of this, roughly 85 percent comes from marine aquaculture (offshore cage farming) and 15 percent from freshwater aquaculture in inland waterways (Shen et al., 2021). Marine coastal farms are located in the Johor Straits - Punggol, Serangoon/Loyang, Lim Chu Kang and Pulau Ubin producing species such as grouper, seabass, snapper and milkfish (Singapore Food Agency, 2022c); freshwater farms produce Asian seabass, milkfish, grey mullet, snappers, golden pompano, hybrid groupers and shrimp (Shen et al., 2021).

Non-food species fall into three groups: aquaculture feed (microalgae, macroalgae, phytoplankton, zooplankton and other planktonic organisms); ornamentals (fish, corals, shrimp and molluscs); and organisms used in flow-through or recirculating systems to improve marine environmental conditions (Leal et al., 2018). Two main factors limit local production to about 10 percent: limited coastal area and species range, and heavy reliance on global supply chains. To reach the 30% target, Singapore must convert these challenges into opportunities.

3.2 Species for food and non-food farmed in Singapore

The Singapore Food Agency regulates and licenses land- and sea-based farms (Singapore Food Agency, 2022b). Diseased fish represent a commercial risk, and stocks are affected when processes are not robust. The farming cycle for *Lates calcarifer* (Asian seabass) comprises five stages, fertilised egg, larva, fry (juvenile), fingerling and broodstock completed over up to five years; males are typically harvested at about two years and nine months, while females are retained longer to continue the cycle (FAO, 2009; Shen et al., 2021). Offshore, Singapore Aquaculture Technologies Pte Ltd operates floating tank-based farms (a 3,000 m² floating tank) using data- and AI-driven Recirculating Aquaculture Systems (RAS) for disease prevention and performance monitoring (Singapore Aquaculture Technologies, 2022). Onshore, Apollo Aquaculture Group Pte Ltd uses land-based RAS to recycle and reuse water with 24/7 monitoring and control; its modular three-tier design enables high-rise farming and can be dismantled and re-established away from the coastline, including in urban areas (URA Singapore, 2017).

Waste falls into three categories; solid, dissolved and pathogenic (Miller and Semmens, 2002). In a well-managed farm, roughly 30% of feed becomes solid waste (Miller and Semmens, 2002).

3.3 Challenges and opportunities

There are two main reasons for the 10 percent limited aquaculture production contributing to local food supply. Firstly, limited coastal regions and species for farming, second being heavily reliant from global fish food supply chains. Hence to achieve 30% production local food supply, the Island nation recognises Challenges and Opportunities from the current food production environment (Table 2).