

3.4 Study and review of the fish farming process

Singapore Food Agency regulates and provides licenses to fish farms both land and sea based in the island nation. The list of licensed farms is available from the Singapore Food Agency (2022b). Diseased fish is a business/commercial risk and fish stocks are impacted when processes are not robust.

Table 2 Description of Challenges and Opportunities

Description of Challenges and Opportunities	
Challenges	Opportunities
Global Supply Chain Issues (Food Security)	Increase Local Fish Production
Limited coastal regions	Utility in Urban Environments
Labour cost and Skilled Workforce	Freshness and Longevity
Energy cost	Deployment of Technologies such as Auto-feeder and Internet-of-Things (IoT), water monitoring systems and Recirculating Aquaculture Systems (RAS)

Fish farming process for *Lates calcarifer* Asian Seabass comprises 5 cycles completed up to 5 years. Male Asian Seabass is intended for harvest within 2 years and 9 months, and females are kept longer to continue the 5 cycles from Fertilisation of egg, Larva, Fry (Juvenile), Fingerling and broodstock (FAO, 2009; Shen et al., 2021).

3.4.1 Farming system offshore

Two main system types are seen in Singapore's offshore farming: the 3,000 m² floating tank and the recirculating aquaculture system (Singapore Aquaculture Technologies, 2022). In the Island-nation Singapore Aquaculture Technologies (SAT) Pte Ltd employs smart farming pioneering floating tank-based fish farms with data and artificial Intelligence driven RAS (Recirculating Aquaculture System). Enabling disease prevention and performance monitoring systems for multifactorial data analysis.

3.4.2 Farming system onshore

In Singapore's onshore farming there are also two systems, the fish transfer pump and the manual feed process (URA Singapore, 2017). Apollo Aquaculture Group Pte Ltd uses a Land-based food fish culture system to prevent disease in fish food. The RAS (Recirculating Aquaculture System) is also used in land-based fish farming operations. The intent is to recycle and reuse water resources, 24-hour monitoring system and control system is used in their farming environments. Innovation is essential and for this company, a prototype modular three-tier farm enables high-rise farming of fish. The modularity of the structure allows it to dismantle and set up a farm away from the coastline even in urban areas.

3.4.3 Waste removal and cleaning

There are three categories; Solids, Dissolvable and Pathogenic Waste (Miller and Semmens, 2002), in an effectively managed farm, approximately 30% of the feed used will become solid waste. Table 3 summarises each waste category and the corresponding cleaning or control approach (Miller and Semmens, 2002).

Table 3 Waste removal and cleaning

No.	Type of waste	Cleaning / control
1	Solid waste from uneaten feed and faeces; if not cleared, becomes total suspended and total dissolved solids.	Rapid capture reduces the dissolved organic load.
2	Dissolved waste (ammonia, nitrite, nitrate, phosphorus, organic matter); un-ionised ammonia, excreted through the gills, is the most toxic form.	Autotrophic bacteria convert ammonia to less toxic forms; providing a large surface area for bacterial growth is the most effective approach.
3	Pathogenic waste; farms can increase potentially pathogenic organisms in effluent.	Chlorination, ultraviolet radiation and ozonation; UV treatment occurs in a chamber and is not harmful downstream.

3.4.4 Review of safety practice and standards in fish farming

Safety standards in fish farming are unique and developed over years of research in global fish farming industries; these standards are non-exhaustive and adapted to the requirements and capacity of localities. There are no