

Industry and operator documentation. Publicly available descriptions of production systems operated by licensed Singapore farms were used to characterise the technologies in current local use. Two operators were selected as illustrative cases, one offshore and one onshore, on the basis that they are licensed by the Singapore Food Agency, operate at commercial rather than pilot scale, and have publicly documented their production technology. These cases are illustrative of the systems in use and are not presented as a representative sample of the sector.

2.3 Selection criteria

Material was retained where it met all of the following criteria: published in English; directly concerned with aquaculture production systems, aquaculture automation, or occupational safety and health in aquaculture or a closely comparable primary industry; and either applicable to tropical or land-constrained production settings, or providing a standard or framework transferable to such settings.

Material was excluded where it addressed fish biology, genetics, nutrition or disease without reference to production process, workforce or safety; where it concerned capture fisheries rather than aquaculture, except where the occupational safety content was explicitly transferable; where it was promotional material without a verifiable technical or regulatory basis; and where a more recent authoritative version of the same standard or dataset was available.

No formal quality appraisal instrument was applied to individual studies, and no meta-analysis was undertaken. This is a limitation of the review and is discussed in Section 4.7.

2.4 Risk assessment framework

The risk assessment reported in Section 3.5 follows the three-step methodology set out in the Code of Practice on Workplace Safety and Health Risk Management issued by the Workplace Safety and Health Council in Singapore (WSH Council, 2011), supported by the risk management guidance of the Ministry of Manpower (Ministry of Manpower, n.d.). The three steps are hazard identification, risk evaluation and risk control.

Hazards were identified by decomposing each activity into its constituent work steps and classifying the hazards encountered at each step under the categories used in the international aquaculture occupational safety literature: safety, physical, chemical, biological, ergonomic and psychosocial (Lloyd's Register Foundation, 2021). Risk was evaluated using the semi-quantitative matrix specified in the Code of Practice, in which severity and likelihood are each rated on a five-point scale and multiplied to give a Risk Priority Number (RPN), which is then classified as low, medium or high risk. The matrix and classification bands are reproduced in Figure 1.

Risk controls were assigned following the hierarchy of controls, in which elimination and substitution are preferred to engineering controls, engineering controls to administrative controls, and administrative controls to personal protective equipment. Where the risk assessment tables in Section 3.5 record personal protective equipment as an existing control, the additional control column identifies the higher-order measure recommended. Two activities, feeding and harvesting, were selected for assessment because they are performed at high frequency across the production cycle, they occur in both manual and automated modes in Singapore farms, and they involve direct worker interaction with water, live stock and moving machinery.

The risk assessments presented are generic worked examples applied to a representative aquaculture process. They were not conducted at a named facility, and the ratings should be read as illustrative of the method rather than as an audit of any particular farm. A site-specific assessment would be required before the ratings could be relied upon operationally.