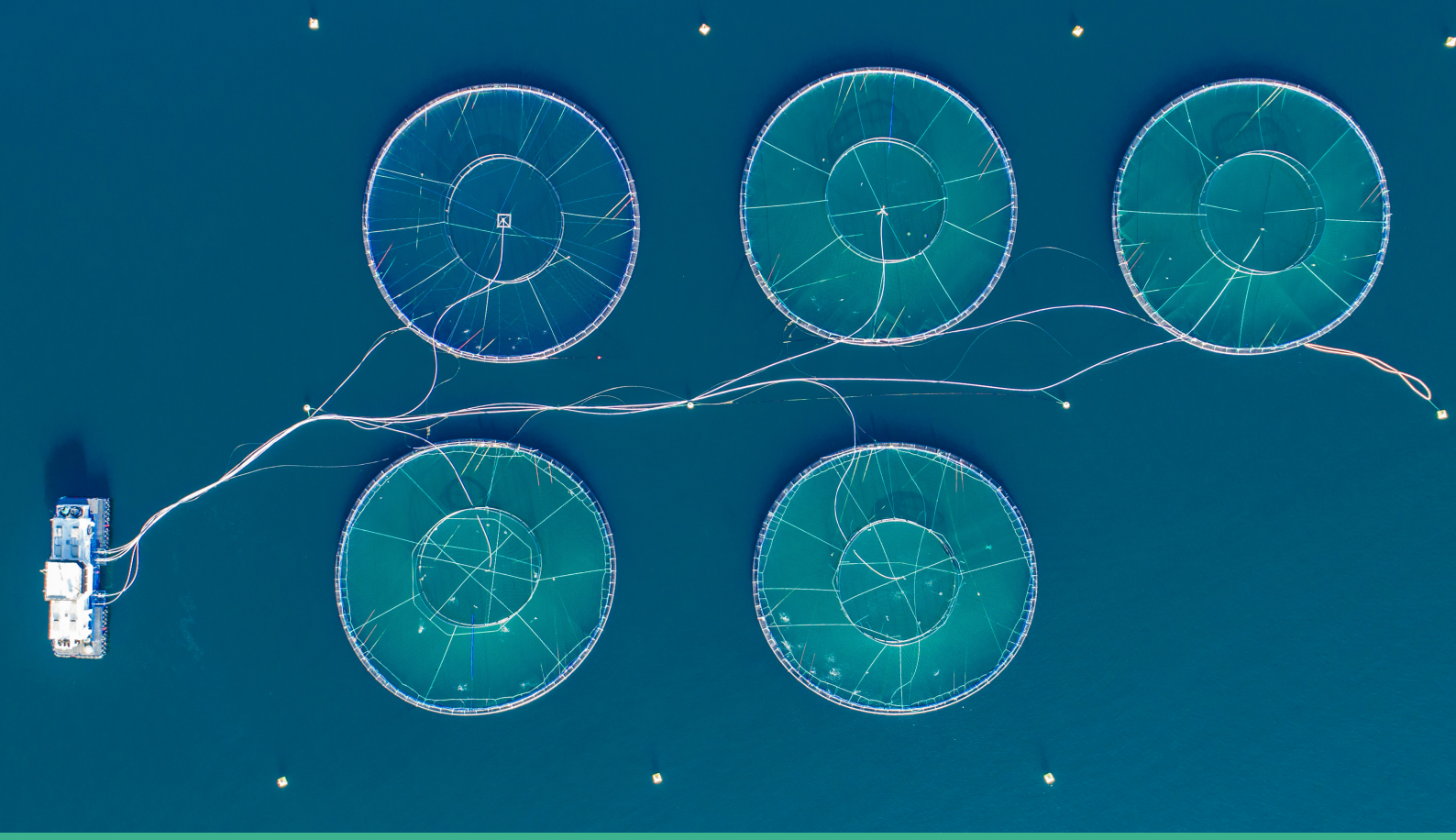

Occupational health and safety in the aquaculture industry – a global review

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Occupational health and safety in the aquaculture industry – a global review

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RS Standards is at the forefront of chain standards development and improvement frameworks and is leading initiatives in sustainability, fisheries management, fishing and supply chain standards internationally with leading organisations.

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Executive summary

Every 15 seconds, a worker dies from a work-related accident or disease. Every day, 6,300 people die as a result of occupational accidents or work-related diseases – more than 2.3 million deaths per year. Annually, 317 million accidents occur on the job; many of these resulting in extended absences from work [5] (see reference page 38).

This report identifies a set of indicators that influence occupational health and safety (OH&S) in aquaculture. It reviews some of the latest published literature on OH&S in aquaculture and uses a set of desk top country reviews to help identify the role of different indicators and their importance.

Aquaculture, the farming of aquatic organisms (including fish, molluscs, crustaceans, and aquatic plants), is the fastest growing food sector in the world. It occurs in all regions, across all economic settings, from artisanal to multi-national, in all environments and even where water is a scarce commodity. In 2018, global aquaculture production of animals (fish and invertebrates) was 82.1 million tonnes (Mt), and aquatic algae 32.4 Mt. Total fish production is expected to expand to 204 Mt in 2030. Aquaculture production is projected to reach 109 Mt in 2030, an increase of 32% (26 Mt) over 2018 [2]. 20 million people are directly employed in aquaculture and another 60 million in downstream seafood occupations. There is a wide range of occupational activities that reflects the diverse forms of aquaculture, from basic labouring to seafaring to technical to managerial. Employment is dominated by small-scale aquaculture producers residing in Asia.

This report focuses on the evidence for OH&S incidents in the global aquaculture industry and evidence on the effectiveness of OH&S interventions to reduce such incidents. OH&S hazards in aquaculture have been categorised as falling into six categories covering safety, physical, chemical, biological, ergonomic, and psychosocial aspects [1].

While many studies have focused on the environmental impacts of aquaculture, and more recently an increase in attention on social issues such as child and bonded labour, by comparison there has been less attention on OH&S risks to aquaculture workers, particularly for low- and middle-income countries (LMICs). Indeed, a relatively recent (2017) Food and Agriculture Organization (FAO) project that reviewed the evidence on OH&S incidents in peer-reviewed and grey literature found that very few studies (3%) were reported from LMICs. Most studies focused on the OH&S data for operations farming fish and crustaceans and less so for those farming molluscs and aquatic plants. Preventive approaches, based on the hierarchy of control measures to reduce health risks associated with hazardous exposures, occur mainly in well-resourced high-income countries.

The FAO project separated OH&S outcomes into two groups: occupational diseases and disorders and injury-causing accidents. Musculoskeletal disorders were by far the most common, followed by respiratory disorders, which may indicate greater exposure to various chemicals during bath treatments of stock. The main injuries were caused by falls (including slips) and object blows. Net entanglement and skin injuries were also fairly common incidents.

It is hypothesised that the FAO findings may underestimate occurrence of many occupational injuries and diseases in the global aquaculture industry, due to underreporting, particularly from LMICs. The granularity of reporting systems in many countries does not allow data extrapolation – at best, reporting of incidents in the aquaculture industry are aggregated within agriculture / fisheries / forestry-type reported data. Types of accidents / incidents are not reported sufficiently and there is no standardised approach for their reporting. Even when there is a mandate for OH&S reporting, access to this data was problematic.

The lack of management / regulation governing small-scale aquaculture operations, mean there are considerable uncertainties on the exposure of workers on smaller-scale farms to OH&S hazards. The large number of undocumented workers in the informal work sector in regions such as Asia and Africa are likely to be more vulnerable to poor work conditions and worker violations and hence at increased risk of exposure to OH&S hazards.

This review identified the higher-level indicators that influence the risk landscape of health and safety in aquaculture settings. The seven indicators identified were:

- country governance
- country regulations and their implementation
- production system type and pace of aquaculture development
- commercial large scale versus small-scale
- operating environment
- social-cultural factors; and
- extent of safety systems and third-party certification.

However, currently there is limited evidence that supports the relative influence of any of these indicators and further investigation is needed to explore how they interact with one another and how they effect OH&S risks and risk outcomes in aquaculture.

The rapid growth of the aquaculture sector has meant that policy and regulation can lag. The capacity for countries to develop, implement and enforce OH&S regulations varies significantly and is often correlated with the level of economic development. The FAO has emphasised the need for improved aquaculture governance globally to reduce the likelihood of what they term 'social dumping', where labour codes may be jeopardised as countries compete to remain attractive to companies and foreign investments. To improve aquaculture governance, the FAO has suggested a range of actions from improving monitoring and enforcement, greater conditions on licenses and leases, limiting ownership size and improved governance on foreign ownership participation.

Business level OH&S interventions can fall into the following categories:

- hazard control at source – involves measures aimed at removing or substituting a hazard
- hazard control along path – this group of interventions comprises occupational measures aimed at reducing exposure to the hazard along the path of exposure; and
- hazard control at the worker – interventions that act at the level of the worker.

Through third-party certification, current aquaculture schemes provide a high level of assurance that higher operating standards are achieved in practice. Where certification programmes contain criteria for worker welfare, this provides a very useful framework for raising awareness and improving practice within a business. It also promotes activity on where improvements can be made and this may help the overall business culture for OH&S.

Recommendations

The research identifies stark differences in the availability of OH&S information associated with aquaculture across geographic regions.

Some regions, typified by a higher development status, have progressed more comprehensive OH&S systems (including policy, regulation, reporting and accountability) applicable across all work sectors and some have progressed implementing and reporting tools specific to their aquaculture sectors. Other regions have far less mature and identifiable frameworks and scant or no available data for evaluating the performance of OH&S in aquaculture. Where reporting is evident, data is often amalgamated and not sector specific.

The lack of comparative data indicates a clear need for a comprehensive framework for evaluating and reporting the current status of OH&S in aquaculture that can be applied consistently at country, regional and / or aquaculture systems level. Its development would require an international approach with multi-stakeholder and disciplinary inputs (government, industry, institutional, NGO, academia, etc.). It would need to:

- define and agree universal standards and metrics. This review identifies some potential indicators that influence OH&S performance at country and sector level (e.g. governance, policy, pace of aquaculture development, industrialisation, environmental setting). These would need further development and consensus building across the group, co-ordinated by an independent organisation
- create a mechanism for its application and reporting. The approach would need a defined process to ensure independence, credibility, and repeatability and build upon current established standards for consistency in data collection (e.g. UN ILO); and
- establish endorsement from the major international organisations associated with labour and aquaculture (e.g. UN ILO, FAO, WHO).

A framework is essential in the creation of an evidence base collection system. It can operate as a benchmark process and allow OH&S performance to be measured consistently. Overtime, it would allow the impact and success of intervention programmes to be measured against standardised performance metrics for OH&S.

1. Introduction

Lloyd's Register Foundation published its Foresight Review of Food Safety in 2019, the findings of which are based on research involving interviews with over 100 industry experts[1] from around the world. The three core areas identified by the Foundation as the focus of its future efforts are:

- food safety education and training
- traceability; and
- safety and sustainability in the seafood sector.

This is one of three related to these topics focuses on the evidence for OH&S incidents in the global aquaculture industry and evidence on the effectiveness of OH&S interventions to reduce such incidents. The evidence in this report and supplementary country profiles addendum[2] has come from a desk-based review exercise and input from aquaculture producers and OH&S experts.

1.1 Context

Aquaculture has been practised in some regions for over 2,000 years. However, in the modern context, aquaculture is still considered one of the newer food production systems in the world. Most countries have an aquaculture industry (even those without coastline and with limited water resources) and there is an incredible array of diversity of species farmed, in production systems, and techniques, organisational scales and in the degrees of technology used. According to recent FAO statistics, over 20 million people are directly employed in aquaculture and another 60 million in downstream seafood occupations [2] (see reference page 38). Similarly, there is a wide range of occupational activities that reflects this diversity in aquaculture, from basic labouring to seafaring to technical to managerial.

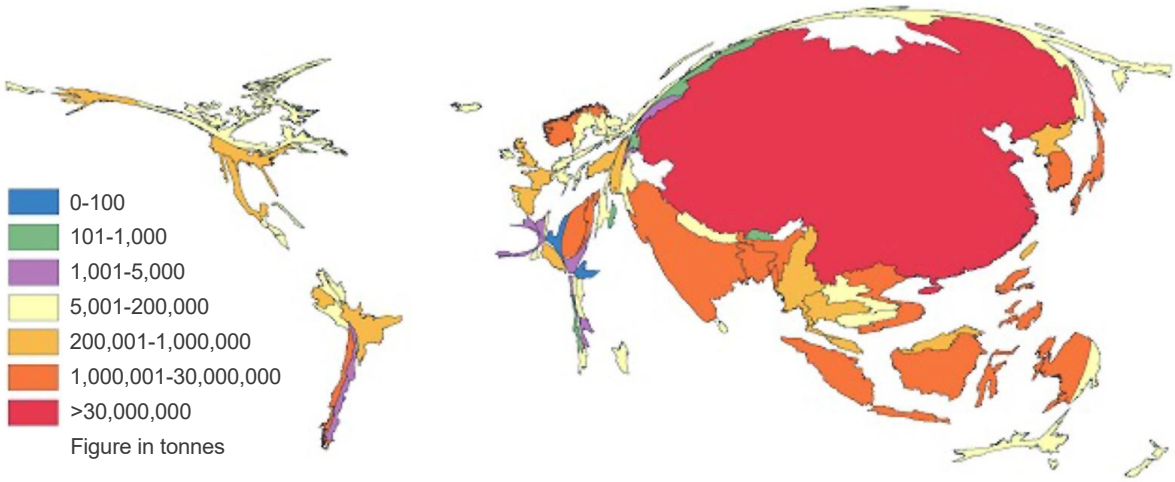

Figure 1: Key aquaculture producing countries in 2015, note the importance of China and the Asian region more broadly[3]

1 Experts interviewed include food safety specialists from global food brands, academics from several leading universities, representatives from Lloyd's Register's specialist food assurance team and several NGOs.

2 https://info.lrqa.com/l/12702/2021-11-15/c92cyq/12702/1636996964D0Ef1ilW/All_Country_Profiles_supplement.pdf

3 http://www.fao.org/fishery/naso-maps/national-aquaculture-production-1950-2015/all-carto/en/

Aquaculture is a rapidly growing sector. In 2018, global aquaculture production of animals (fish and invertebrates) was 82.1 million tonnes (Mt), aquatic algae 32.4 Mt, and 26,000 tonnes of ornamental seashells and pearls [2]. By 2029, animal aquaculture production is projected to reach 105 Mt, 10 Mt more than the wild caught sector[4]. Growing demand for seafood and relatively low feed prices are also behind the future growth of aquaculture. Profitability in the sector is expected to remain high or stable in the next decade especially for species that require smaller amounts of fishmeal and fish oil and that have established markets.

China (and Asia generally) is the leading aquaculture producer globally by a significant margin; China producing 63.7 Mt, followed by Indonesia (16.6 Mt) and India (5.7 Mt)[5] (see Figure 1). The growth rate for aquaculture production in many regions has generally remained consistently high (Annex 1) and it is the fastest growing primary production sector globally.

The rapid growth of the aquaculture sector has meant that policy and regulation is often lagging. While many studies have focused on the environmental impacts of aquaculture farms, far fewer have focused on the OH&S risks to aquaculture workers, particularly for low- and middle-income countries (LMICs). This is a significant oversight, with more than 20 million workers in the aquaculture industry globally, with a large proportion in LMICs [1].

OH&S hazards in aquaculture have been categorised as falling into six categories covering safety, physical, chemical, biological, ergonomic, and psychosocial aspects (Table 1).

Table 1: Common aquaculture hazards in aquaculture [1]

Hazard category	Causative agents / processes
Safety	Slips and trips, falls, needle-sticks, unprotected machinery, electricity, diving, underwater entrapment, explosions, firearms, tractor power take-offs, confined spaces
Physical	Heat and cold, vibration, solar radiation, noise
Chemical	Sensitisers, irritants, antibiotics, toxic gases
Biological	Sharp teeth, spines, poisonous insects, snakes, allergens, microbes, fish feed, endotoxins
Ergonomic	Heavy lifting, prolonged standing, awkward postures, repetitive motion, overexertion, lack of visibility
Psychosocial	High demand-low control situations, shiftwork, remote locations and lone work, abusive social environment

4 OECD-FAO Agricultural Outlook 2020-2029, Fish https://www.oecd-ilibrary.org/sites/4dd9b3d0-en/index.html?itemId=/content/component/4dd9b3d0-en

5 https://www.statista.com/statistics/755857/major-aquaculture-producers-worldwide/

1.2 Recent global studies of relevance to project

In 2017, the FAO Committee on Fisheries committed to prioritise OH&S issues in aquaculture[6]. An international team was established to synthesise OH&S knowledge concerning more than 20 million, often vulnerable, aquaculture workers found globally. It reviewed global OH&S aquaculture data and compiled a synthesis of the scientific and grey literature from 1960 to 2017 (460 publications in total) [3]. This included OH&S data from official country reports, industry, labour ministries and workers' compensation boards.

The key findings from this review were that very few studies (3%) were reported from LMICs, and most studies focused on the OH&S data for operations farming fish and crustaceans, and less so for those farming molluscs and aquatic plants [3]. Preventive approaches, based on the hierarchy of control measures to reduce health risks associated with hazardous exposures, are existent mainly in well-resourced high-income countries.

The reviewers separated OH&S outcomes into two groups: occupational diseases and disorders and injury causing accidents. The most common occupational diseases in order of prevalence included musculoskeletal disorders, respiratory symptoms and asthma, skin infections, followed by dermatitis and urticaria. Occupational infections such as leptospirosis (33/100,000PYs[7]); and decompression illness in divers (incidence: 0.57–26.19/10,000PYs) were expressed as % occurrence in 100,000 person years. The most common injuries included falls, blows from an object entanglement, pricks / cuts / punctures, high voltage exposures, and needlestick injuries (see Table 2 summary).

Table 2: Measures of occupational morbidity in aquaculture workers (*range of various studies, PYs person-years) [4]

Occupational injury / disease	Outcome measure: prevalence (%) / incidence (PYs)
Injuries due to:	
Falls	10-49/10,000 PYs*
Object blows	14-37/10,000 PYs*
Net entanglement	29/10,000 PYs*
Pricks / cuts/ punctures	29/10,000 PYs*
High voltage	8/10,000 PYs*
Needlesticks	5 self-injections per 1,000,000 vaccinations
Diseases	
Musculoskeletal disorders	21%-63%*
Respiratory disorders and asthma	4%-65%*
Skin disorders	
Infections	2,2%-15.7%*
Dermatitis	6%
Urticaria	0.7%
Leptospirosis infection	33/10,000 PYs*
Decompression illness (divers)	0.57-26.19/10,000 PYs*

6 The outputs from study were discussed at ifishconference https://ifishconference.ca/post-conference-workshop/

7 PYs = person years (used to denote the incidence of occupational injuries per amount of time spent)

OH&S global perspectives and evidence

Workplace safety is considered by World Health Organization (WHO) as a priority for health promotion in the 21st century. ILO and WHO reports indicate that in manufacturing industries many employees suffer from workplace injuries. Every 15 seconds, a worker dies from a work-related accident or disease. Every 15 seconds, 153 workers have a work-related accident. Every day, 6,300 people die as a result of occupational accidents or work-related diseases – more than 2.3 million deaths per year. Annually, 317 million accidents occur on the job; many of these resulting in extended absences from work [5]. As a result of the ever-increasing pace of worldwide liberalisation of trade and economies, as well as technological progress, the problem of occupational accidents and occupational diseases are becoming more and more of global concern, particularly in developing countries [6].

Concepts and models of risk and risk outcomes have been developed for OH&S in aquaculture. In this report, we use a popular definition of hazard and risk used by OH&S professionals.

- Hazards are generally described as a source of potential damage, harm or adverse health effects on something or someone.
- Risk entails the combination of likelihood and consequence, in this case to a negative outcome (injury, fatality, disease) as a consequence to exposure to the hazard.

How risk can be influenced is the focus of workplace safety interventions. These can be either preventative (removal of the hazard e.g. swapping a caustic chemical to a more neutral one) or mitigation of the risk to exposure (wearing PPE; eye protection, gloves, etc.) and reduction in the post exposure impact (e.g. first aid interventions, access to an eye bath station).

For the purpose of this report, Figure 2 illustrates how the aquaculture hazards identified in Table 1 interact with the OH&S interventions (see Section 4.5 for detail) which led to the risk outcomes (see Table 2).

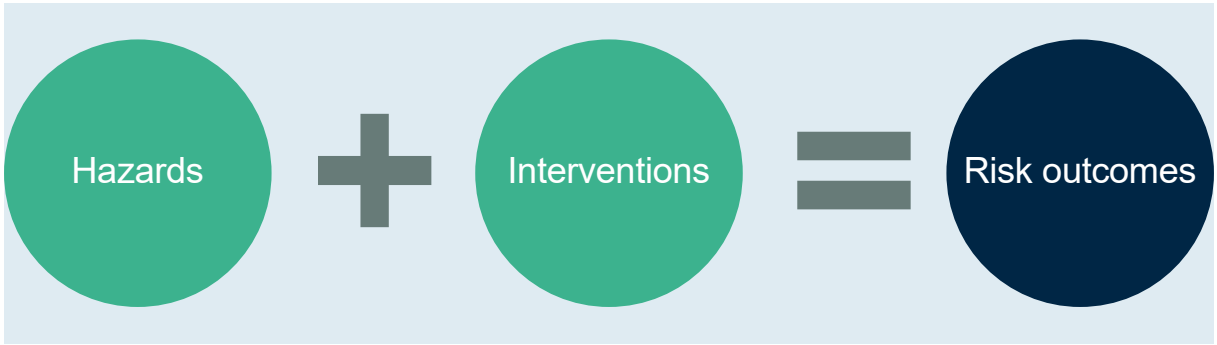

Figure 2: Framework for understanding how potential hazards related to risk outcomes

1.3 Aims and objectives

This report looks to provide insights to the following questions:

1. What is the landscape of traditional and emerging occupations within aquaculture?
2. What is the scale of incidents, accidents, and other relevant safety outcomes within the areas of the global aquaculture industry (i.e. emerging sectors)?
3. What data is available that allows these safety outcomes to be assessed globally for the aquaculture industry?
4. What are the leading indicators of safety in related areas (including traditional industries), and what interventions have been demonstrated to improve safety that might be applicable to the aquaculture industry as it develops?

The FAO-led collaborative review [3] has provided a useful baseline of information on which to further develop. However, given the absence of a single global repository of aquaculture OH&S data for comparative analysis, the approach taken in this review has been to further build evidence and insights that address the above questions through profiling seven contrasting countries that are globally or regionally (in the case of Africa) significant aquaculture producers (see Section 2.2 for further rationale).

The method underpinning this approach is outlined in Section 2, each country profile summarised in Table 6 (pages 24-26), and key findings summarised in Section 4. The intent of undertaking this approach was to provide a standardised reporting framework enabling a comparative analysis to be undertaken between different countries.

Conclusions and a series of recommendations on how this work could be developed are presented in Section 5.

2. Methods and research approach

2.1 Data sources

Initially, a desk-based review was undertaken of key information sources (publications and websites) for aquaculture OH&S using the following search terms:

aquaculture health and safety / occupational health and safety

From this initial review the FAO OH&S project was identified [1][3][4]. (Details of the 460 publications used in the FAO project were captured in a supplementary spreadsheet entitled 'Aqua OH&S resource library'[8], coming from a bibliography by Waterson [7]. Many of these publications pertained to studies undertaken in wealthier countries, such as Norway and the UK.) There is no single authoritative source of aquaculture OH&S data globally.

The data used to inform this report has come from a variety of sources, including the following:

- scientific papers
- websites, including; FAO, ILO, WorldData, Statista, Global Slavery Index, Corruption Perceptions Index
- certification programmes and publicly available reports, including; ASC, BAP, Global GAP[9]
- grey literature, including news articles, country national aquaculture strategy reports etc.; and
- personal communications via email, LinkedIn messaging, personal experience, phone calls (see Annex 3 for consultees).

2.2 Country profiles

In order not to replicate the FAO findings, and with the purpose of building upon this work, a prototype standardised data reporting template was created at a country-level, to help enable specific comparisons to be made between regions addressing the objectives outlined in Section 1.3.

An additional reason for undertaking a country level analysis is the hypothesis that work organisation factors affecting OH&S will be influenced by the strength of country level OH&S legal framework, institutional resources, and governance. The criteria underpinning the choice of countries were:

- region – development status (with focus on LMICs), ensuring insights are captured from Africa, Asia, and Latin America to consider the influence of governance and cultural factors in the comparison
- production systems and method (species) – to consider how the type of aquaculture sector and its organisation (small scale, fragmented versus large scale, integrated) influence the risk profile. The countries chosen were to reflect the spread between marine versus onshore, and intensive versus extensive / small-scale production
- aquaculture growth potential – focus on countries where aquaculture is economically important and has high growth potential; and
- other factors of interest – e.g. labour market, incidents of child labour, poor worker welfare, gender bias, undocumented and migrant workers, informal work sectors, etc.

8 https://info.lrqa.com/l/12702/2021-11-15/c92cz2/12702/1636997076SnvBODN6/Aqua_OH_S_resource_library_Nov_2021.xlsx

9 See Annex 4 for more detail on these certification schemes

The seven country profiles are shown in the supplementary addendum entitled 'All Country Profiles'[10]. The initial OH&S reporting template was developed for Norway (see addendum). Norway was chosen as representing a global leader in aquaculture OH&S and acting as a benchmark to which the other countries could be compared. The key highlights from other countries profiled are as follows:

Africa

- Kenya – with 14,000 tonnes (t) production; it has strong government support to develop sector; small-scale producers still dominate the sector.
- Ghana – 76,000 t production; there has been rapid growth over past decade; child labour is an issue.

Asia

- China – 63.7 Mt production; is by far the world's biggest aquaculture producer (range of freshwater and marine sectors); it has traditional and emerging sectors of aquaculture; there is a lack of OH&S culture.
- Bangladesh – 2.06 Mt production; it is in the top 10 worst countries for workers' rights,

Latin America

- Chile – 1.2 Mt; it is the world's second biggest salmon producer (after Norway); it has experienced rapid growth and intensification; there is an history of environmental concerns.
- Guatemala – 17,000 t; is in the top 10 worst countries for workers' rights; it has poorly regulated workplace environment in general.

2.3 Comparative analysis

To facilitate the collection of information in a consistent manner and to allow comparisons between countries to be made, a prototype set of OH&S indicators and scale were developed covering:

- presence of regulations
- implementation and monitoring
- reporting
- farm specific actions
- incidents and accidents; and
- fatalities.

10 https://info.lrqa.com/l/12702/2021-11-15/c92cyq/12702/1636996964D0Ef1ilW/All_Country_Profiles_supplement.pdf

A short analysis of aquaculture (volume, value, species, main production systems) was undertaken for each selected country. Information that could influence and inform the risk landscape for aquaculture was identified; growth potential of aquaculture (species, systems, setting – inland / marine / cage / pond, etc.), workforce demographics / patterns (intensity – output / worker, % of workforce employed in aquaculture, presence of migrant workers, undocumented or informal, less regulated work environments, evidence of child labour, evidence of use of PPE). Growth rate, technology, emerging systems and how this may influence emerging occupations, was also considered.

A first iteration of a scoring matrix for each indicator was developed. Further details of the reference scale used to score the criteria for each indicator is provided at the back of the supplementary addendum[11]. At this stage the scale is purely hypothetical and will require further testing and iteration before being published. Kite diagrams were plotted for each country as a visual representation of
the extent of effectiveness a country scores against each criterion. As noted, the development of scoring indicators is a first step in establishing a numeric scale that could provide a level of objectivity for basing broad comparisons. The review followed a three-step methodology, based on the lead author scoring the indicators initially, followed by the second and third authors confirmation to allow justifications and any adjustments to be made.

The country profiles were based on a top-level review of information and, in many instances, very little information on OH&S specific to aquaculture was available. The reviewers sought dialogue and input from in-country informants, who had working experience in the country / region, as well as their own insight where they had personal experience of aquaculture within the region. The country profiles are therefore based on published literature informed by personal comments formed from experience.

The country profile information was used to inform the landscape of traditional and emerging occupations within each country. Locating data sets that established the scale of incidents, accidents and relevant safety outcomes within each country, proved extremely difficult due to the absence of data. The review of country OH&S regulatory frameworks and reporting systems support these outcomes, i.e., in a good number of cases there are poorly developed reporting systems for aquaculture and often this was reflected across other sectors e.g. agriculture. The authors considered to what extent country development status and governance influenced the OH&S reporting frameworks (Section 4.3).

Good data sets appear to be available for certain countries, Norway is the noted example in this review, and this is supported by other studies. The data is reported at the business unit level for aquaculture and although not publicly available, can be purchased with a good level of granularity, specific to OH&S incident by type [8].

Overall, the country profiles provided a useful approach to inform the overall investigation on the main influences on OH&S in aquaculture and discovery of possible leading indicators of safety in related areas (traditional, modern, scale, informal / formal) and these are highlighted and summarised in this report (Section 4).

11 https://info.lrqa.com/l/12702/2021-11-15/c92cyq/12702/1636996964D0Ef1ilW/All_Country_Profiles_supplement.pdf

3. Landscape of traditional and emerging occupations within aquaculture

SUMMARY

- The number of aquaculture workers globally is estimated to be over 20.5 million; the majority residing in Asia, and participating in small-scale aquaculture operations inland (freshwater fish) and in coastal strips (shrimp ponds).
- Large / medium commercial enterprises tend to dominate production in the Americas and Europe. Salmon production in particular is heavily commercialised.
- Farms in Asia and Africa rely heavily on a temporary contracted workforce.
- While organisations such as UN FAO aggregate and publish broad data sets of species groups (volume and value) at country and regional level, and by marine / coastal, brackish, and inland production, there was very little data on farm systems and occupation by type.
- Aquaculture is being viewed as an important growth sector by many LMICs and there is a growing trend towards consolidation and intensification of production.
- There is competition for marine space and resources for competing uses (e.g. offshore wind, fishing, conservation purposes, etc.) and driven by environmental concerns, intensifying regulation on access. As a consequence, there is increasing interest from aquaculture enterprises in developing offshore aquaculture. Interestingly, the same environmental pressures are also driving innovation for certain species such as Atlantic salmon using recirculating (water) aquaculture systems (RAS) and closed containment systems to reduce negative impacts.
- RAS technology has developed significantly over the last two decades and while perceived as high risk by investors, is gaining traction as an alternative farming system to open net pen and pond farming. To what extent the OH&S risk of fish farmers using this technology is in comparison to traditional systems, is not understood. The elimination or reduction in risks from hazards such as to exposure to the elements, drowning and physical injury from falls and slips associated with at sea conditions, would appear entirely plausible.
- There has been increasing interest and growth in seaweed (both micro and macro-algae) farming, not least because of its various traditional uses, including as a food, animal feed, fertiliser, food processing ingredients, nutraceuticals and pharmaceuticals, and recent interest as a potential biofuel.

3.1 Current status

Overview

The FAO provides global aquaculture production data every two years; the latest 2020 report provides data for 2018 [2]. This data has been analysed in a variety of ways (see Annexes 1 and 2), though perhaps most informative for this review is the distinction between inland versus marine and coastal aquaculture (Table 3), with the former producing over 51 Mt, and the latter producing over 30 Mt.

The number of fish farmers globally is estimated to be over 20.5 million, with the majority (19.6 million) living in Asia (Table 4), the largest aquaculture producer globally (see Figure 1). To a large extent, aquaculture in this region is based on lower technology and farmed by small-scale producers and family-run businesses. While there are some examples of larger scale corporations in these regions, large / medium commercial enterprises tend to predominate production in the Americas and Europe, which have larger capital investments and relatively smaller workforces per unit of production.

Table 3: Aquaculture production of main species groups by continent in 2019 [2]

Category	Africa	Americas	Asia	Europe	Oceania	World
	(thousand tonnes, live weight)					
Inland aquaculture						
Finfish	1,893	1,139	43,406	508	5	46,951
Crustacea	0	73	3,579	0	0	3,653
Molluscs	...	...	207	...	...	207
Other aquatic animals	...	1	528	0	...	528
Subtotal	1,893	1,213	47,719	508	6	51,339
Marine and coastal aquaculture						
Finfish	291	1,059	3,995	1,892	92	7,328
Crustacea	6	888	4,834	0	6	5,734
Molluscs	6	640	15,876	680	102	17,304
Other aquatic animals	0	...	387	3	0	390
Subtotal	302	2,587	25,093	2,575	200	30,756

Table 4: Aquaculture – world employment for fishers and fish farmers, by region [2]

Region	1995	2000	2005	2010	2015	2018
	(thousands)					
Africa	69	100	189	255	355	386
Americas	279	257	241	336	377	388
Asia	7,426	12,355	14,826	17,910	19,533	19,617
Europe	98	104	100	118	115	129
Oceania	6	8	8	6	10	12
Total	**7,878**	**12,825**	**15,364**	**18,625**	**20,390**	**20,533**

The current trend towards intensification also means that, globally, production in certain sectors (e.g. salmon farming) has become increasingly oligopolistic in that a handful of multinational companies dominate production[12].

Demographics

A 2014 study by the FAO on the governance of aquaculture employment [9] found that most aquaculture workers are in the age range of 20–39 years. This is a similar profile across regions, though being particularly pronounced for Africa, likely reflecting the younger demographics of the continent.

A factor driving the OH&S risk profile will be types of occupation of those involved in the enterprise. The various types of job role could include the following:

- managerial (executives / senior managers)
- office workers in clerical / administration roles
- technical and specialist roles (e.g. hatchery manager, farm site manager, feed manager, fish health manager)
- farm operatives (e.g. pond preparation, maintenance, fish husbandry, fish feeding, fish treatment, fish stocking, fish harvesting)
- diver (farm maintenance, fish mortality removal); and
- sea craft and machine operator (service vessels, hydraulic and electrical, cranes, winches, pumps).

Figure 3 indicates the percentage of permanent employees in different job classifications for those farms with data available. As can be seen, the bulk in all regions are occupied as labourers; in the only farm to provide data in Africa, more than 90% were classified as labourers. The lowest proportion was in Canada, but generally at least half of all employees are classified as general labour. The differences in other roles between regions may be due to the types of business surveyed and top-heavy hierarchy in certain regions with high levels of capital investment in technology (e.g. Canada), and also a product of the survey in that in many cases supervisors, technicians, and labourers may do the same types of work [9].

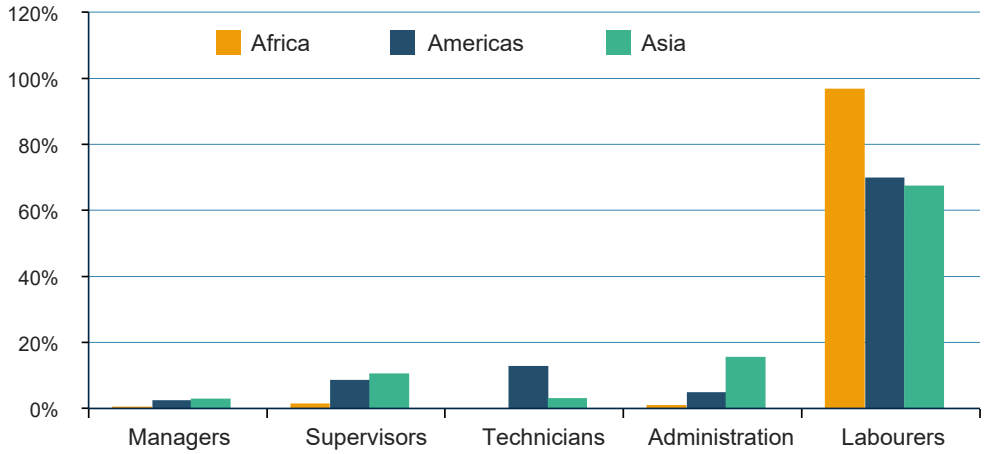

Figure 3: The proportion of aquaculture workers by job classification in different regions, 2009 [9]

12 Mowi is still the undisputed largest salmon farmer in the world. With 422,400 tonnes of salmon, the company harvested more than double number two on the list, Lerøy Seafood Group. With the next four, SalMar and Cermaq, the top five consists solely of Norwegian companies. Although Cermaq is Japanese owned, by the conglomerate Mitsubishi, the company still has its headquarters in Norway. (https://salmonbusiness.com/these-are-the-20-biggest-salmon-farmers-in-the-world/)

Figure 4 illustrates that in all the regions of FAO the case studies, except in Asia, three quarters of employees were male. For Asia, most employees at three of the farms surveyed were women. The proportion of women among total employees in India was 94%, in the Philippines 80% and in Thailand 75%. The high proportion of women in the enterprises surveyed in India and Thailand reflects their processing orientation [9].

A significant difference between farms is their reliance on part-time contract workers (Figure 5). When averaged across farms, the Americas as represented by Canada, hired very few part-time or seasonal workers; almost all are permanent workers entitled to full benefits, including pension benefits. At the other extreme, some of the farms studied in Africa and Asia relied primarily on contracted labour, rather than permanent labour. In the case of one operation, the rationale of the management for not hiring more permanent workers was the uncertain economic situation in their country and the cost to the company of entitlements if permanent labour had to be released [9].

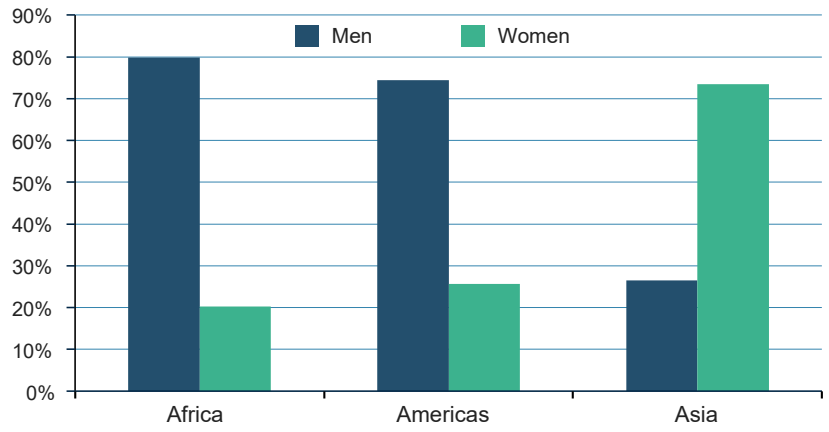

Figure 4: The proportion of aquaculture employees by gender in different regions, 2009 [9]

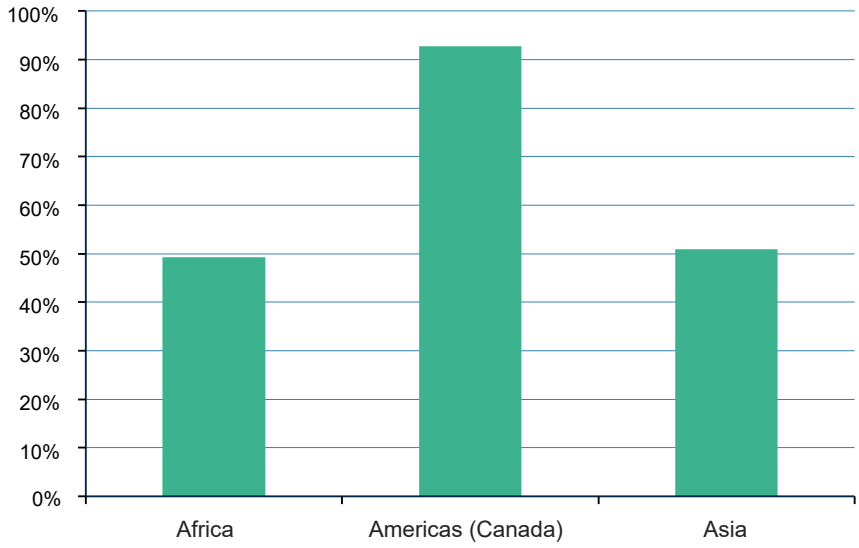

Figure 5: The proportion of permanent workers in different regions, 2009 [9]

Activity breakdown

Unfortunately, there is no global data source breaking down aquaculture production into the key types of production system (see Table 5). Statistics on this are of variable quality between countries and generally poor. Categorisation (of volumes, value) is based on marine, coastal, brackish, and inland water systems which provides some insight into farm systems in operation.

Inshore aquaculture can involve pond farming or pen / cage farming in rivers and lakes, water flow through systems (raceways) or more recently recirculating aquaculture systems (RAS) that can be housed outdoors or indoors (see page 19, onshore production for further detail. Many pond farms utilise low lying brackish water systems within coastal margins. Marine aquaculture can involve intertidal[13] or near shore culture (for example oysters, seaweed), coastal net pens, rope grown mussels, and offshore culture systems (including fish cages and structures for shellfish cultivation).

Each production method will have its own unique OH&S risk profile. Some types of production will be intrinsically riskier than others, for example, operations using heavy machinery, and operations occurring on / in exposed water bodies.

Table 5: General types of production method by species group

Species group	Production systems
Salmonids Coastal marine near and offshore cage systems	Coastal net pens Offshore RAS Ponds (trout farming) Raceways Tanks
Seaweed Coastal marine near and offshore floating lines, rafts Can include shore-based tank systems for propagation	Coastal Offshore culture on structures
Oysters Coastal, nearshore marine and brackish	Coastal Intertidal Submerged bottom Offshore culture on structures Suspended on floats or rafts
Mussels	Bottom mussels Coastal Offshore culture on structures
Shrimp, tilapia Inland enclosed pond, lake (cage) and brackish, coastal pond systems	Intensive pond culture Semi-intensive pond culture RAS
Marine finfish cage systems Temperate, sub and tropical species (gadoids, basses, breams, cobia, baramundi grouper, snapper, trevally, etc.)	Coastal net pens RAS Ponds Tanks
Marine bivalves Coastal, nearshore, offshore	Submerged bottom Intertidal
Marine gastropods Nearshore and onshore	Raft systems / lantern nets / trays / other suspended and anchored systems Tanks, raceways, including RAS systems

13 Between the high-water mark and low-water mark.

3.2 Emerging sectors

Important revenue earner for LMICs

For both developed and developing countries, one of the main objectives of both private and government sectors is economic return. Maximising investment returns for private enterprise and driving GDP for governments and, in developing countries where incomes are low, increasing export earnings is seen as an important mechanism to stimulate revenue from foreign currencies and taxes. There are occasions where government policy may specifically include increasing domestic fish consumption via aquaculture and often these can be dual policies with species suited to domestic consumption (cheaper to grow) and those with higher export potential. Within the country profiles examined in this study, examples of these approaches can be seen.

Fish consumption in Ghana is approximately 720,000 Mt annually however, current local fish supply amounts to only 400,000 Mt. A $53 million government initiative launched in 2017 in the northern region of Ghana aims to boost aquaculture, creating jobs and providing affordable food. In addition, to encourage local aquaculture sector growth and increased production, the government has banned the import of farmed fish, with an additional import tax of 15% on any kind of seafood.

Growth in the Ghana sector has been rapid with production increasing from only 950 tonnes in 2004 to 76,630 t in 2018. There is scope for further development due to vast natural water bodies (e.g. Lake Volta is 8,500km^2) and backing by government initiatives. The majority of output is from cages, but the sector is mostly represented by small-scale pond systems. Cage systems typically require bigger infrastructural investments which may either lead inward investment or government supports and where these are lacking, may increase risk of lower quality cage infrastructure leading to higher OH&S risk exposure.

Shrimp farming in Bangladesh (inland and brackish) is emerging as an important aquaculture activity, with high export earning potential. Bangladesh has a ‘blue growth’ plan to continue the increase in aquaculture production while also targeting improvements in product quality. Fisheries and aquaculture play a key role in Bangladesh’s economy and, as the country becomes less reliant on depleting capture fisheries, the aquaculture sector will need to continue to grow to meet the demand both for the export (predominantly shrimp for the EU) and domestic markets. A recent example of how shrimp is being targeted as a potential growth area can be seen with the government piloting cultivation of the Pacific Vanammei (whiteleg or king) shrimp to boost competitiveness.

In Guatemala too, there has been an increased demand for fish, with consumption increasing to almost 3kg per capita from a low base of <1kg in the mid 1990s. Aquaculture production increased 11.79% a year during 2000–2017, from 3,963 t to 26,360 t, mainly due to intensive shrimp farming.

A growing population forecast, estimated to reach 21 million by 2030, means there will be further increases in demand for fish and seafood on the domestic market. At the same time, there is a strategic plan is to increase exports by utilising new technologies to increase production to meet expanding export sales.

Increasing intensification of aquaculture systems

There has been a general trend in recent years towards the consolidation and intensification of production in different aquaculture sectors [10] across all regions. This has both an upside and downside for OH&S risk. The use of automating technology and robotics in feeding and harvesting is seen as a way to reduce risk in certain sectors, for example marine cage farming, by reducing the amount of time staff are exposed to hazardous situations.

However, intensification can also increase risks particularly if heavy machinery and vessels are used without people having appropriate skills and training. For example, Thorvaldsen et al., 2020 reported on the interview outcomes of 35 employees in Norwegian salmon aquaculture, with different job functions. The study noted that both managers and operational personnel agree that the quality and quantity of measures aimed to improve safety have increased in recent years. However, the study noted that some elements of safety management were found to be more useful than others and an observation that biased focus on procedural compliance with written documentation might miss out on identifying the safety measures fish farmers see as valuable [11]. Marine salmon farming remains a 'hands on' physical activity that takes place in a dynamic environment. This would suggest that management approaches to OH&S intervention may have become too theoretical and should ensure they are practically based and include the knowledge from experienced practitioners.

Intensification generally leads to economies of scale, and the ability to employ a workforce with a wider skillset (e.g. technical and managerial), which would be expected to potentially formalise OH&S risk assessment and management within an organisation. Though this would be largely dependent on whether there is a good OH&S culture within the organisation; in other reviews, similar analogies were drawn [5], with at least some companies likely to cut corners to maximise returns, for example through underinvesting in PPE. Indeed, an interesting future area of study would be to investigate the extent to which country OH&S regulations and penalties for breaking laws provide the incentives for improved company performance on OH&S issues.

Offshore expansion

There is competition for marine space and resources for several uses (e.g. offshore wind, fishing, conservation purposes, etc.). As a consequence, there is increasing interest from aquaculture enterprises in developing farms miles offshore[14, 15] and onshore in contained, recirculated water systems.

Offshore development has its advantages as farms can be sited with reduced impact on the environment, as effluents will be more effectively diluted and dispersed, and it will not impact on the amenity attached to coastal areas. However, offshore structures need to be robust to withstand the demands of the environment and the more hazardous nature of offshore work will mean OH&S risks will need to be carefully managed.

In terms of growth in specific sectors, there has been increasing interest and growth in seaweed farming, not least because of its various uses, including as a food source, food processing ingredients, pharmaceuticals, and recent interest as a potential biofuel. The OH&S risk profile for seaweed farming will likely be similar to that of shellfish production, and be dependent on whether production is intertidal, in the coastal zone or further offshore.

Onshore production

For onshore production, RAS is a technology that has rapidly evolved but its use is still in relative infancy. In RAS, the culture water is purified and reused continuously[16]. RAS can involve culture of fish outdoors and indoors. It uses technical interventions to manage the water quality parameters (e.g. temperature, dissolved oxygen, nutrient load reduction). Given the carefully controlled environments of RAS systems, one would assume that OH&S risks would be reduced, though other considerations may come into play (e.g. electrocution). Advantages of onshore sites include location nearer to markets, reduced carbon impact and other environmental benefits, and access to a wider labour pool.

14 For US see https://thefishsite.com/articles/ensuring-the-sustainable-growth-of-the-us-offshore-aquaculture-sector

15 For EU member state aquaculture plans see https://ec.europa.eu/oceans-and-fisheries/ocean/blue-economy/aquaculture/aquaculture-multiannual-national-plans_en

16 For further detail on RAS see https://www.aquaculturеid.com/recirculating-aquaculture-system/

4. OH&S information review and discussion

In this section, insights from the seven country profiles (supplementary addendum[17]) have been used to illustrate key points.

4.1 The scale of incidents, accidents, and other relevant safety outcomes within the global aquaculture industry

SUMMARY

- A recent FAO review of OH&S data (1960 to 2017) relating to aquaculture operations identified 460 publications; a key finding was that only 3% of these studies were reported from LMICs. There was a general bias in data reporting for the farming of fish and crustaceans, over farming of molluscs and aquatic plants.
- Musculoskeletal disorders were by far the most common disease, followed by respiratory disorders, which is not surprising in that most farm workers globally are manual labourers and exposed to various chemicals during water treatment.
- The main injuries were caused by falls (including slips) and object blows. Net entanglement, and skin injuries were also fairly common incidents.

Data overview

Few studies have consolidated aquaculture OH&S data at a global level. Based on a synthesis of the primary aquaculture OH&S studies in the academic and grey literature, the prevalence of occupational diseases and incidence of injuries was estimated for the industry globally [4] (refer to Table 2 page 6).

Musculoskeletal disorders were by far the most common disease, followed by respiratory disorders, which is not surprising in that most farm workers globally are manual labourers and exposed to various chemicals during water treatment. Infections and skin diseases were also reasonably common. The main injuries were caused by falls (including slips) and object blows. Net entanglement, and skin injuries were also fairly common incidents.

17 https://info.lrqa.com/l/12702/2021-11-15/c92cyq/12702/1636996964D0Ef1ilW/All_Country_Profiles_supplement.pdf

Given the reporting bias to countries where aquaculture OH&S issues would be expected to be reasonably managed, it is hypothesised that these figures would actually be a significant underestimate of the prevalence of many occupational injuries and diseases. This needs to be further tested.

Key data gaps

The obvious methodological challenge is reporting bias. This is because the more comprehensive data of aquaculture OH&S is largely confined to commercial enterprises in wealthier countries, such as Norway, USA, Canada and Australia, with only 3% covering from studies of aquaculture OH&S in LMICs [3].

Even when there are laws requiring reporting of accidents these are not implemented (workers / managers do not know this should be done) or workers are reluctant to report issues due to fear of retribution and loss of pay. Corruption may also be an issue, for example, inspectors and unions may be paid off and workers silenced. The granularity of reporting systems does not allow data extrapolation – at best reporting of incidents in the aquaculture industry are aggregated within agriculture / fisheries / forestry-type reported data. Types of accidents / incidents are not reported sufficiently and there is no standardised approach for reporting of aquaculture OH&S incidents.

Thus, there is currently no objective basis for determining which aquaculture sectors are riskier to work in than others. All that can be said is that the risk profile will be different for each sector and it is likely that country development status has a strong influence. It is hypothesised that the most significant factor driving the risk will not necessarily be the type of enterprise, but the governance and regulatory OH&S framework in place in a country, though there is no direct objective evidence that exists to conclusively demonstrate this in aquaculture.

Extreme natural events will also increase the risk of fatalities to workers in many LMICs, for example farm workers in the coastal strip may be vulnerable storms and tsunamis[18], farmers working inland may be vulnerable to droughts. Only a few studies have examined the climate risks posed to aquaculture workers and these mainly focused on high-risk countries e.g. Bangladesh [12]. Indeed, natural events seem to have been omitted from current OH&S frameworks [1].

18 For example, the Indian Ocean tsunami in 2004 killed at least 225,000 people across a dozen countries, with Indonesia, Sri Lanka, India, Maldives, and Thailand sustaining massive damage. Many of these fatalities could have been workers in the fishing and aquaculture sectors https://en.wikipedia.org/wiki/2004_Indian_Ocean_earthquake_and_tsunami#Economic_impact

4.2 Data availability to allow safety outcomes to be assessed globally

SUMMARY

- The granularity of reporting systems in many countries does not allow data extrapolation.
- Types of accidents / incidents are not reported sufficiently and there is no standardised approach for reporting.
- Large number of undocumented workers in the informal work sector in countries in Asia and Africa will be more vulnerable to poor work conditions and worker violations, and hence at increased risk of exposure to OH&S hazards.
- The lack of management / regulation governing small-scale aquaculture operations, mean there are big uncertainties on the exposure of workers on smaller-scale farms to OH&S hazards.
- Even when there is a mandate for OH&S reporting (e.g. China) getting access to this data is problematic.

Key findings from country reviews

From the country reviews it is apparent that there is a clear difference in the availability of data on OH&S issues in LMICs compared to the Norway benchmark. From Watterson's (2018) review of UK Aquaculture Occupational Health and Safety, a comparative level of data to Norway is evidenced [4].

Norway has an inspectorate, the Norwegian Labour Inspectorate Agency (LIA), that has been established to continuously improve health and safety and environment procedures. Thorvaldsen et al 2020 [11] report that the role of the LIA is simply to ensure that a system is documented although there is evidence it is performance based.

Holmen & Thorvaldsen (2018) [8] also report that internal audits, audits by the regulatory authority and third-party audits are used as part of the monitoring and evaluation of implementation and performance of OH&S. Global market demand is also pushing external certification for OH&S and a range of ISO (OSHAS 18000) and aquaculture specific (Global GAP, Aquaculture Stewardship Council[19]) standards are used. Most of the major salmon aquaculture businesses in Norway carry such certification and a comprehensive regulatory framework for OH&S is in place. Of note, other authors have observed that without the knowledge and judgment of practitioners to guide the development and implementation of safety management systems the theory of safety may not necessarily reflect the risks and measures required for the 'work in practice' [11]. Such regulations may cause an 'over theoretical' response to OH&S management leading to a tick box mentality.

Similar trends are emerging in Chile, with key features of a technically advancing salmon sector and foreign corporate investment. Certification is used to help compete in global markets where sustainability is a key part of large retailer and food service buying requirements, which have evolved to include a greater emphasis on worker welfare.

The review noted some opportunities for improvement in the OH&S systems in Norway, including concerns of overlapping responsibilities that may result in reduced performance or response of the legal system for OH&S and a fast paced, technically advanced evolving industry may result in lag

19 See Annex 4 for more detail on these schemes.

time for adequate health and safety provision. It is also apparent that fish welfare appears to be more specified than worker welfare. Science, specifications, standards, and systems are evidently more advanced for the maintenance of, and prevention of, poor welfare conditions for fish. Welfare and health of stock is of course a fundamental to business performance. Worker welfare may not carry such associated incentives.

Norway in comparison to other country profiles included in this review, is by far the global leader with respect to aquaculture OH&S systems.

As there is a deficit of information to assess OH&S at a global level, the country comparison was used to highlight qualitative differences between countries / regions. For example, some globally significant producers such as Bangladesh, are still largely comprised of small-scale farms, and there is no primary data collection system for OH&S. Large number of undocumented workers in the informal work sector are more vulnerable to poor conditions and worker violations. In Kenya, there are also inadequate data management systems for workplace accident reports.

China is by far the largest aquaculture producer globally, with examples of intensive larger scale commercial operations and a vast majority of small-scale extensive production (particularly culture of freshwater species inland e.g. rice paddy field cultivation). China has developed a comprehensive regulatory framework for worker safety and laws to protect the rights of workers with implementation through the government's Fisheries Safety Authority. Data on reporting does not appear to be publicly available. For small-scale farms, their often rural location and distance to health care services means that there may likely be considerable underreporting of OH&S incidents.

Chile is a globally significant producer of salmon, second only to Norway in terms of production volumes. It is a well developed sector, with many of the largest commercial salmon companies having operations there. In 2014, fatalities in the aquaculture sector were the second highest in the country (just lower than in mining industry) at a rate of 11.3 per 100,000 employees. A report from 2005 data showed 62% of accidents on salmon farms in Chile occurred involved contract workers employed by outside agencies and it is noted that these contract workers generally do not have access to unions and salaries can be 30% less than permanent workers.

In summary, the extent of available data on aquaculture OH&S seems to correlate with the development status of the country, and to what extent it has a OH&S legal framework, and the associated institutional capacity to carry out inspections and reporting (see Table 6 for country summary). Some countries where there is strong top-down governance (e.g. China) may be less inclined to make such data publicly accessible.

Table 6: OH&S SWOT overview of country profiles

Bangladesh	SWOT overview
Production: 2.4 Mt CPI[20] ranking: (out of 180) 146 Employment aqua: 4M < Intensity output / worker: 0.6 Aqua OH&S reporting: Absent	**Strengths:** ILO presence. National OH&S day. Guidelines for chemical use have been developed.
	Weaknesses: Small-scale farmers have poor access to working capital making spend on OH&S unlikely. No primary data collection system for OH&S.
	Opportunities: Recent government focus on regulatory interventions (generally) and at factory level which may lead to wider option and interventions at farm level. Blue growth strategy for aquaculture could attract investor interest and improve OH&S conditions. Simple OH&S interventions would likely see significant improvements in reducing incidences and fatalities. Community / farmer-farmer communications are effective ways to disseminate knowledge, including OH&S. Registration system for chemical use could support focus on OH&S interventions, safe instructions for use, and PPE use.
	Threats: Lack of resources for implementing measures, reporting, combined with corruption undermine efforts to develop a safety culture. Large number of undocumented workers in the informal work sector are more vulnerable to poor conditions and worker violations.
Chile	**SWOT overview**
Production: 1.3 Mt CPI ranking: (out of 180) 25 Employment aqua: 18,315 Intensity output / worker: 70.3 Aqua OH&S reporting: Moderate	**Strengths:** Recent government and industry focus on OH&S training. Well established OH&S committees and regulations governing OH&S. Chile continues to improve its ranking in indexes such as CPI (25) and the Global Slavery Index scores Chile at 162/167 (167 being lowest risk).
	Weaknesses: Regulations have not kept up with the fast pace of aquaculture development. High prevalence of casual workers (75%) makes interventions, such as training, challenging.
	Opportunities: Providing a labour law for diver protection would reduce accidents and fatalities in the aquaculture industry dramatically. Continued growth in number of farms achieving aquaculture certification could increase market share and improve OH&S standards on sites.
	Threats: The industry may prioritise growth, operational efficiency and profit margins ahead of OH&S, exaggerated in periods of market downturns (e.g. impact of pandemics). Environmental pressures and regulations may result in farming in more exposed, open sea locations (as in Norway) and increase risks with the associated hazards.

20 Corruption Perceptions Index (CPI). See https://www.transparency.org/en/cpi/2020/index/nzl#

Table 6 continued: OH&S SWOT overview of country profiles

China	SWOT overview
Production: 66.1 Mt CPI ranking: (out of 180) 78 Employment aqua: 4.7M < Intensity output / worker: 13.9 Aqua OH&S reporting: Sporadic	**Strengths:** ILO presence. China has developed a comprehensive regulatory framework for worker safety and laws to protect the rights of workers. Recently, (2018) a state department, Ministry of Emergency Management (MEM) responsible for workers and workplace safety, was formed. There is a government Fisheries Safety Authority reported to conduct inspections in aquaculture. Data on reporting does not appear to be publicly available.
	Weaknesses: Implementation of the measures is weak and reactive. The sheer size and scale of aquaculture (large number of small-scale farms that operate in a traditional and informal manner) makes inspection and interventions extremely challenging.
	Opportunities: There is increasing focus on OH&S reporting and interventions in other industrial workplace environments. China Academy of Safety Sciences and Technology (CASST) (state run under MEM) and China Occupational Safety and Health Association (COSHA) (non-profit organisation) are both involved in OH&S, including providing technical support, information, and education. China Blue Sustainability Institute is China's first NGO focused on sustainable fishing and aquaculture. The organisation is involved in multi-stakeholder engagement, and realistic practices utilising scientific information and may provide a network to aid communication of importance of OH&S to rural farmers.
	Threats: There is a moderate risk for forced labour (high risk in fishing) – China scores as medium risk at 111 out of 167 on the Global Slavery Index. There is evidence of employer influence on officials and trade unions (China ranks 78 out of 180 on Transparency International CPI). Rural nature and distance to health care services and poorly developed trauma care systems worsen impact of work-related injuries. Underreporting and challenges in accessing complete and independent data.
Ghana	**SWOT overview**
Production: 76,630 t CPI ranking: (out of 180) 75 Employment aqua: 58,000 Intensity output / worker: 1.3 Aqua OH&S reporting: Absent	**Strengths:** The Labour Act, 2003 (Act 651) entitles workers to work under satisfactory, safe and healthy conditions. The National Health Insurance Scheme covers for immediate medical care for OH&S accidents.
	Weaknesses: Workmen's Compensation Law, 1987 is outdated in terms of compensation to workers and levels of risk in today's workplace. The National Health Insurance Scheme specifically excludes workplace health and safety requirements such as rehabilitation. Non-existent / weak infrastructure for monitoring OH&S.
	Opportunities: There is no national policy on OH&S in Ghana (however Oppong[21] reports one is drafted but not enacted) and could be further developed. Aquaculture has been highlighted as one of the top priorities in the government's development agenda for Ghana. Foreign / international companies have developed sites in Ghana and could offer leadership in OH&S. Solutions via FAO / government programmes (e.g. Chorker oven) have demonstrated successful implementation of OH&S interventions.
	Threats: Evidence of corruption in government institutions (Transparency International CPI 75th of 180) and enforcement of regulations is poor. Lack of comprehensive OH&S policy. Lack of specifically trained occupational health professionals. Poor literacy rate (59.5%) among workers hampers efforts to support workplace interventions.

21 Oppong S (2014) Accident and Safety Issues in Ghana. Presentation for PhD thesis. University of Ghana

Table 6 continued: OH&S SWOT overview of country profiles

Guatemala	SWOT overview
Production: 28,317 t CPI ranking: (out of 180) 149 Employment aqua: 40,000 Intensity output / worker: 0.7 Aqua OH&S reporting: Absent	**Strengths:** Guatemala has made good progress in tackling child labour through introductions of new protections, although not focused on aquaculture. There is a Labour Ministry.
	Weaknesses: Lack of labour inspectors and resources within the ministry responsible for OH&S. Child labour within agriculture sector (and hence potentially aquaculture) remains a major issue in Guatemala. Large informal work sector.
	Opportunities: Evidence that the Labour Ministry is considering developing the Health and Safety Regulation giving the Labour Inspection greater powers to inspect workplaces and to impose administrative sanctions. Guatemala (along with Belize, Costa Rica, El Salvador, Honduras, Nicaragua, and Panama) is part of OSPESCA – an inter-governmental organisation aimed at promoting the co-ordinated and sustainable development of fisheries and aquaculture in the region.
	Threats: Corruption – Guatemala ranks low at 149 out of 180 on the Transparency International CPI. Health care is chronically underfunded and there is significant marginalisation for girls, and indigenous groups in rural areas (e.g. access to education).
Kenya	**SWOT overview**
Production: 15,124 t CPI ranking: (out of 180) 124 Employment aqua: 7,840 Intensity output / worker: 1.9 Aqua OH&S reporting: Absent	**Strengths:** The government programmes emerging for safety and health in education curriculum at all levels to promote OH&S culture. Still relatively small scale – if OH&S procedures brought in now and could roll out with the growth of the sector. Cage culture reduces use of chemicals and antibiotics, due to improved fish health, outcomes in turn reducing worker exposure to chemicals.
	Weaknesses: Inadequate data management systems for workplace accident reports. Inadequate integration of occupational health services into all levels of healthcare system. Inadequate research to identify workplace risks arising from new and developing industries and shortage of OH&S skills across public and private sectors.
	Opportunities: The National Aquaculture Policy (2011), National Aquaculture Strategy and Development Plan (2010-2015) and Aquaculture Communication Strategy (2012) are due to be reviewed and would benefit from specific sections on OH&S. Several aquaculture development programmes underway reaching large part of sector – could help educate in OH&S. A growing industry – opportunity to implement OH&S culture and interventions while still small scale.
	Threats: Corruption within police and government – Kenya is one of the worst in the world ranking 143 out of 180 on the Transparency International CPI. Lack of financial resources for enforcement of regulations. Poor educational levels and hence little awareness and appreciation of occupational safety and health among employers and workers. Focus on large industrial sectors at expense of small rural businesses with fewer employees, and newer sectors e.g. aquaculture. Cost of and access to healthcare. Fear of loss of employment leads to under reporting by workers.
Norway	**SWOT overview**
Production: 1.5 Mt CPI ranking: (out of 180) 7 Employment aqua: 7,825 Intensity output / worker: 186 Aqua OH&S reporting: Present	**Strengths:** Organised and functional governance and legislature for the development and regulation of OH&S requirements, including reporting systems. Employees have rights to unionisation and safety in workplace environments, including aquaculture. Inspection is routine, third-party certification (Aquaculture Specific Standards including OH&S) (BAP, ASC, GGAP) are routine.
	Weaknesses: Some overlap in reporting systems and compliance activities may create tick box mentally.
	Opportunities: Rationalisation of overlaps between the agencies, adopt and learn from offshore oil and gas, include OH&S in all aspects of adopting new farm technologies.
	Threats: Offshore develops at a faster pace than OH&S interventions. Margins fiercely protected through efficiencies that reduce interventions for OH&S.

4.3 Leading indicators of aquaculture health and safety risks

Indicators of aquaculture OH&S risk can be categorised in a number of ways, particularly where attempts are made to identify the root causes of particular types of OH&S accidents or incidents such as falls, cuts, drownings, etc. This review aimed to identify the higher-level indicators that influence the risk landscape of health and safety in aquaculture settings. However, currently there is only very limited evidence that supports any of these indicators and further investigation is needed to explore how these factors interact with one another to drive OH&S risks in aquaculture and the risk outcomes (see Figure 6 for suggested framework).

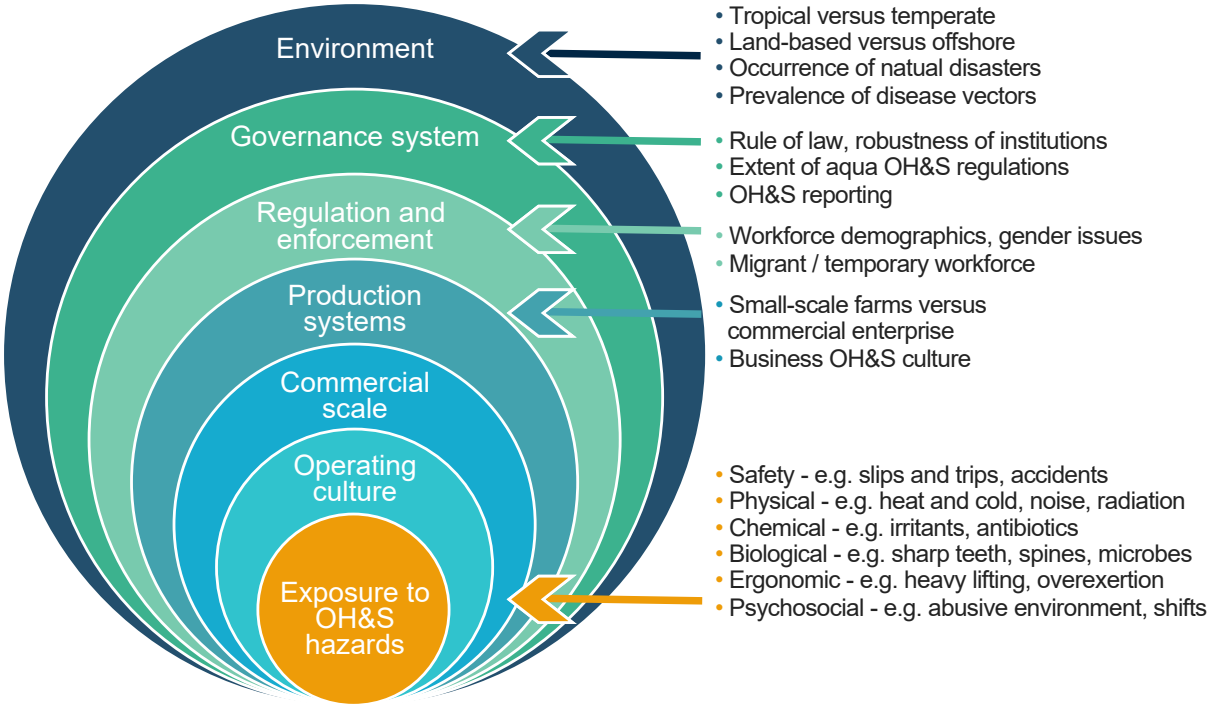

Figure 6: Conceptual framework for how different indicators combine to form the degree of exposure to OH&S hazards (i.e. the risk). This requires further research to verify.

From the country profiles, it is hypothesised that the seven following factors will have the greatest influence on aquaculture OH&S outcomes (in no particular order):

- **Country governance** – robustness of institutions, rule of law, extent of corruption will influence to what level development of the aquaculture sector is socially (and environmentally) responsible.
- **Country regulations and implementation** – a robust inspection system could be an important aspect i.e. a sense of enforcement and consequences for poor practice. Lack of any regulation or consequences likely driving risks of non compliance.
- **Production system type and pace of aquaculture development** – particularly where this includes the adoption of new technology and exploitation of new environments.
- **Commercial large scale versus small scale** – For commercial / large scale, in countries with poor regulation / enforcement, indigenous investors may be less concerned about compliance, external investors with CSR[22] already defined and brand value / reputation will be more interested in compliance and using their own models for this, where it does not exist.

22 Corporate social responsibility

- **Environment** – extremes and how dynamic it is. Climate change will drive unpredictability of local weather events and probably escalate / amplify known events such as typhoon seasons. Some areas will be more vulnerable to natural disasters such as earthquakes and associated tsunamis, also tropical storms and hurricanes.
- **Social-cultural factors** – modern, stable regimes more likely to be lower risk and than developing, politically unstable regimes. Attitude to migrant / displaced people / attitude to rural, marginalised, lower educated makes them more vulnerable to the risk of exploitation.
- **Extent of safety systems and third-party certification** – formal safety management systems (e.g. ISO 45001) provide organisations with a framework through which they can pro-actively improve health and safety performance as verified via third-party certification. Additionally, employee OH&S criteria (and worker welfare) is becoming a key part of the various international aquaculture third-party certification schemes. The use of certification standards is skewed towards the larger, better resourced organisations although there are improvement models that aim to support small farm holdings. It is plausible to assume that countries where these schemes have greater penetration will have improved OH&S outcomes.

These factors have been identified from a review of primary studies and country level analysis. The relative importance of each in determining OH&S outcomes needs to be properly explored, though is conceptualised in Figure 6. This could form the basis of future work that builds the evidence base for better understanding what conditions are needed to foster an OH&S culture within the global aquaculture sector and improve social responsibility issues more broadly.

These factors are now examined in more detail.

Country governance and corruption

Governance is the process of decision-making and the process by which decisions are implemented (or not implemented), and 'good governance' is the responsible conduct of public affairs and management of public resources[23]. Corruption is the antithesis of this, and the Corruption Perceptions Index (CPI)[24] was one of a number of indicators used to inform the initial choice of country profiles. Transparency International, that runs the CPI, defines corruption 'as the abuse of entrusted power for private gain… corruption erodes trust, weakens democracy, hampers economic development and further exacerbates inequality, poverty, social division and the environmental crisis'. Corruption is correlated with the development status of a country, though it should be noted that some LMICs score quite favourably on the CPI and some wealthier countries less so.

23 Principles of Good Governance https://www.coe.int/en/web/good-governance/12-principles

24 See https://www.transparency.org/en/cpi/2020/index/nzl#

In the context of the aquaculture industry, corruption could lead to new aquaculture developments being sited without proper environmental planning or licensing. Lack of transparency could also mean government officials are susceptible to industry lobbying efforts to reduce employment regulations and worker protections.

The interest and influence of global organisations and forums (e.g. UN, ILO, FAO, etc.) and local NGOs in aquaculture activities in a country could be a useful proxy for good aquaculture governance. Access to unions or labour associations will also ensure worker voices drive improvements in worker conditions. If aquaculture growth and investment policies are well managed, a balance can be struck between improving worker welfare and the productivity (and export earnings) of the country [9].

Country regulations and implementation

From this review, most countries have developed a legal framework for OH&S at some scale. Countries that have defined clear policies and established implementation measures, such as inspectorates and enforcement tools, may see greater success in developing and improving OH&S across all sectors, including aquaculture; but where policy or political will is undefined, there are examples of inadequate resource allocation and /or corruption which results in ineffective implementation. Norway is an example of a country that has a defined policy for aquaculture development linked with clear social goals that include safety in workplace settings. In the examples considered by the authors in this report, far less information was available of OH&S (from country profiles) policy for countries including Guatemala and Bangladesh, but at the same time, there was evidence of aquaculture growth policies, ambition and strategy (e.g. Bangladesh).

In certain countries, regulations may still be catching up to the types of aquaculture operation / occupation. For example, diver accidents in Chile happen all too frequently[25]. Claudio Faundez, president of the National Union of Divers of Chile, blamed the exclusion of divers from the Labour Code in Chile, combined with lack of representation within the Mutual Law and lack of regulation in place. He stated “The salmon industry takes advantage of these legal loopholes and hires the most impoverished and the cheapest services”[26].

Production system type and pace of aquaculture development

In Section 3.2 some emerging aquaculture sectors were identified. A key theme from the country profiles was that when OH&S regulations fail to keep up with the pace of emerging aquaculture sectors this creates loopholes that unscrupulous operators can exploit.

Expansion of aquaculture activities further offshore may increase the number of at-sea hazards faced by operators (e.g. large swells, changeable conditions, and exposure). If the legal incentives and penalties to prevent excessive risk taking do not exist (or are not enforced) then this could lead to increases in the number of OH&S incidents.

Inward investment from overseas companies can have advantages, for example if it allows the sector to modernise, accessibility to equipment to reduce the physicality of work tasks, provision of PPE, and access to medical care and social security.

25 A Chilean scientific researcher stated in personal communication that “I feel diving in Chile salmon farming could be the most concert issue in OH&S. I have some reports on yo-yo diving that could be fatal in some cases. In Chile, is common diving use another diving called hookah diving, it is without a cumbersome or heavy scuba tank. It is just a line, and the air tank is on surface.”

26 https://www.fishfarmingexpert.com/article/divers-demand-change-after-spate-of-salmon-farm-deaths/

Governments having a clear policy and regulatory framework for responsible aquaculture development (i.e. an 'aquaculture growth strategy') will help ensure that workers benefit from the activities of more intensive commercial enterprises.

Commercial large versus small scale

Many of the larger aquaculture companies will have standardised risk management systems. However, commercial pressures may mean excessive risk taking during peak harvesting times, for example, harvesting when sea conditions are sub-optimal, and long working shifts. Some companies may also under-resource the provision of PPE to workers, particularly if they view this as an unnecessary cost. This could be particularly problematic in areas where labour is cheap and plentiful, and workers protections (e.g. sickness pay / injury compensation) are non-existent.

The risks for small-scale producers may be similar, particularly if there is lack of any OH&S training or risk awareness. Even if provided with adequate PPE, if workers are not educated on how to use it and its importance, it is next to useless in mitigating risks. Likewise, absence of key skills, such as trained first aiders, may also mean relatively minor injuries could have significant impacts on the persons affected.

Perceptions of risk in operations may also differ between regions, depending on how farm operators view OH&S risks in relation to other everyday risks they face. Access to proper medical care may also be an issue.

Environment

The type of environmental can have a strong bearing on the types of occupational hazards faced by aquaculture workers. Workers in tropical latitudes will be exposed to high temperatures, solar radiation, tropical storms. Workers in temperate and sub-polar latitudes face cold temperatures and a real risk of exposure and hypothermia if they end up in the water.

Tropical environments tend to be more fertile breeding grounds for microbes and disease vectors such as mosquitos and snails. Other poisonous animals such as snakes and various types of marine life may also pose hazards to hand gatherers. Some regions may also be more prone to extreme weather events and natural hazards such as earthquakes and volcanic eruptions.

Social-cultural factors

In many regions, particularly some countries in Africa and Asia, aquaculture operations are dependent on a temporary workforce. This may comprise a significant percentage of migrant workers from other countries and / or displaced ethnic minorities. To the extent that these workers are undocumented may increase the risks associated with their personal and workplace welfare. This potentially may increase OH&S (and general human rights) risks if migrant workers are not treated with respect by farm managers or offered the same employment rights as permanent workers and in the worst examples, leave them vulnerable to bonded and forced labour trafficking. It is far less likely that undocumented farm labourers will have access to professional health and social welfare supports in the region which would also increase risk of post injury secondary disorders and infections.

Another factor potentially affecting OH&S outcomes could be gender-based risk perception. Men will be generally more prone to risk taking than women.

Extent of third-party certification

The key aquaculture certification schemes (e.g. BAP, ASC, and Global GAP) cover internationally recognised principles of social welfare and occupational health and safety in the aquaculture workplace. The core principles include those set by the ILO and international standards for social accountability and for OH&S. These include prohibiting the use of child labour or any form of forced labour, health and safety in the workplace, and fair and equitable working conditions with regulated working hours that allow for sufficient periods of physical and psychosocial rest.

There are many examples from LMICs of aquaculture companies achieving third-party certification (see Annex 4 for overview). The authors of this report note that there can be cost barriers for smaller aquaculture businesses to implement standards and gain certification to international standards meaning implementation can be limited to larger organisations. Certification also supports access to export market opportunities, where discerning buyers in developed regions have implemented their own CSR policies and require their suppliers to demonstrate they can respond to these. Arguably the primary motivation for improvement is derived from growth in profits and the shareholders may have less genuine interest in the welfare of employees although, as an intervention, certification does serve to bring about improvement.

Nevertheless, the extent to which production in a country is covered by third-party aquaculture certifications could provide a useful proxy that OH&S issues are reasonably well-managed. It is also worth noting that the main standards bodies in aquaculture continue to develop their own improvement models and measurement tools for small-scale farming systems.

4.4 Interventions that could improve safety in the aquaculture industry as it develops

SUMMARY

- The FAO has emphasised the need for improved aquaculture governance globally to reduce the likelihood of what they term 'social dumping', where labour codes may be jeopardised as countries compete to remain attractive to companies.
- To improve aquaculture governance, the FAO suggests the following; improving monitoring and enforcement, license withdrawal, site leases, limit ownership size and limit foreign ownership.
- The capacity for countries to implement and enforce their OH&S regulation varies significantly and often correlates with the level of economic development.
- Business level interventions can fall into the following categories:
  - hazard control at source – involves measures aimed at removing or substituting a hazard
  - hazard control along path – this group of interventions comprises occupational hygiene measures aimed at reducing exposure to the hazard along the path of exposure; and
  - hazard control at the worker – interventions that act at the level of the worker.
- Current aquaculture certification schemes do not provide any guarantees that there is a good OH&S culture within a company. However, certification may provide a useful starting point of awareness-raising within a business on OH&S issues, and discussion of where improvements can be made.

Good aquaculture governance

The FAO has emphasised the need for improved aquaculture governance globally to reduce the likelihood of what they term 'social dumping', where labour codes may be jeopardised as countries compete to remain attractive to companies [9]. The FAO 2014 report states this is particularly important when the aquaculture industry has become oligopolistic and operates in remote locations where it can enjoy power over the labour force as a sole or dominant employer. To remain attractive, communities may be prepared to sacrifice good working conditions, accept reduced wages and salaries, work longer hours without compensation, forgo benefits, or accept employment of minors [9].

To improve aquaculture governance, the FAO suggests the following; improving monitoring and enforcement, license withdrawal, site leases, limit ownership size and limit foreign ownership [9]. Fundamentally this will take political will by the respective country, and efforts to improve the strength of institutions, rule of law, and addressing corruption.

Policies and regulations

Good governance is linked to policies and regulations. While all the countries profiled had a regulatory framework in place to some degree for the OH&S of workers, the capacity for countries to implement and enforce their regulation varies significantly and often correlates with level of economic development.

It could be hypothesised that, where regions have progressed more comprehensive OH&S frameworks in general, they will have a more effective system that also relates to aquaculture. To what extent a structured framework is in place may also influence the safety culture at organisational levels and leading from this, would influence the options and effectiveness of any proposed interventions. Put simply, the implementation of formal safety systems on small-scale farms is likely to be unsuccessful as compared with large farms and interventions, such as on farm practical education, demonstration, training and provision of PPE, will have more immediate impact. That said, mechanisms that promote comprehensive regulatory frameworks covering employment rights (and human rights more generally) and OH&S requirements, underpinned by the legal and financial incentives to ensure company compliance, can be seen as critical for ensuring aquaculture businesses (particularly larger companies) operate responsibly.

Business OH&S culture

Organisational factors that could improve individual work conditions are avoidance of long working hours and ensuring adequate rest between shifts. Workplace risk levels may be influenced by the design of fish farms and equipment and hence occupational health and end user needs should be properly considered in technology development [11].

Businesses could be more proactive in establishing an OH&S culture, with adequate provision of PPE, training to improve employee skills and awareness, and avoidance of excessive risk taking (e.g. attempting to harvest when weather conditions are hazardous). Integrating risk assessment into everyday decision-making should also be undertaken.

Technical interventions

Ngajilo & Jeebhay (2019) categorised technical interventions into the following groups [3]:

- Hazard control at source – involves measures aimed at removing a hazard of substituting another method to avoid a hazard. For example, using an automated fish vaccination machine can reduce the incidence of needlestick injuries, while using a pulley system, cranes, and fish pumps for harvesting fish can eliminate heavy lifting.
- Hazard control along path – this group of interventions comprises occupational hygiene measures aimed at reducing exposure to the hazard along the path of exposure. For example, installing extraction ventilation and use of timer pumps for reducing exposure to formalin in hatcheries, covering tanks and standpipes to reduce noise exposures in fish rearing facilities.
- Hazard control at the worker – interventions that act at the level of the worker. These include administrative procedures and the usage of PPE. These are often the protective measures most widely used by employers due to their associated lower costs in the short-term, but they do not provide absolute protection in the long-term [3].

Advances in technology can also help reduce workers exposure to hazards in some operations. For example, Mowi is moving towards a fully automated and digitalised operation[27], which will mean current manual tasks associated with monitoring and feeding of salmon are phased out. This will reduce the occurrence of accidents (such as drownings, entrapment, etc.) associated with these activities.

Sharing of good practice

Offshore aquaculture operations could potentially learn from other industries such as offshore oil and gas where safety standards have improved significantly over the last few decades. However, the reasons for cutting corners in aquaculture businesses will be different, particularly when there are pressures to harvest irrespective of prevailing weather conditions.

The Fish Safety Foundation noted that a more effective route to developing a safety culture in fishing sectors in Bangladesh was by educating the wives of fishermen on the importance of wearing lifejackets. Education strategies and modes of communication (e.g. verbal rather than written) are important considerations in the implementation of interventions at ground level. Women already play an important role in fisheries and aquaculture businesses in Bangladesh and, since the majority of labour is family members, community based education may prove to be more successful than institutional or formal education settings.

There are examples of mobile applications that can help aquaculture workers manage their exposure to hazards. AquaSafe[28] is a platform for promoting workers' safety and health in aquaculture, with actions aimed at aquaculture workers and producers, students and professionals. It addresses the main hazards and associated health risks in aquaculture work environments. AquaSafe can be used as a checklist and assessment of occupational risks. It assists in the decision-making of injury and disease prevention methods, techniques or measures, through information on eliminating or reducing risks, engineering controls and / or administrative controls, and use of PPE.

Third-party standards and certification schemes

As discussed in the previous section, aquaculture third-party certification schemes have the potential to bring about improvements, though costs may prohibit smaller holdings. Standards operate at the business level which in isolation may not be as effective where there is a weak or absent legal framework for OH&S systems implementation. Improvement models that focus at both business and institutional level will be of greater value in these regions.

Third-party standards have brought about improvements in OH&S at farm level, evidenced by the growing number of active businesses that engage in certification. Activities that lead to the inclusion of smaller aquaculture businesses and holdings could lead to positive outcomes and intervention at the institutional level may support capacity building and improvement in implementation and reporting frameworks.

27 Mowi automation of key farm activities Mowi: 4.0 digitalisation, automation to transform value chain (seafoodsource.com)

28 Aquasafe App – https://play.google.com/store/apps/details?id=br.gov.rs.ddpa_seapi.aquasaude.aquasafe

5. Conclusion and recommendations

This review has provided insights to answer four questions.

1. What is the landscape of traditional and emerging occupations within aquaculture?

Despite the dominance of large commercial enterprises in specific sectors (e.g. marine salmon farming), the majority of employment in aquaculture is in small-scale operations, with most of these workers residing in Asia. Large / medium commercial enterprises tend to dominate production in the Americas and Europe although there are examples in other regions, notably, foreign and domestic investments in Chilean salmon and by Thai Union Group (Thailand and elsewhere). Aquaculture is being viewed as an important growth sector by many LMICs, as evidenced by the country profiles in this review, and there is a growing trend towards consolidation and intensification of production.

With environmental regulation and competition for space intensifying, there is increasing interest from industrial marine aquaculture in developing farms further offshore, and automated technologies will become important features in their management. In many developed countries there has been increasing interest and growth in macro- and micro-algae production, not least because of its various uses, from food to pharmaceuticals, and as a potential biofuel. Interestingly, seaweed farming is considered a traditional practice in many LMICs and in China. In terms of emerging sectors onshore, one still in its relative infancy but gaining traction is the development of recirculating aquaculture systems (RAS), whereby the culture water is purified and reused continuously.

2. What is the scale of incidents, accidents, and other relevant safety outcomes within the areas of the global aquaculture industry defined in 1?

Available data on the scale of OH&S incidents, accidents, and other relevant safety outcomes in the global aquaculture industry have been reviewed by a FAO project. A key finding was that only 3% of these studies were reported from LMICs. Musculoskeletal disorders were by far the most common disease, followed by respiratory disorders, which is not surprising in that most farm workers globally are manual labourers and exposed to various chemicals during water treatment. The main injuries were caused by falls (including slips) and object blows. Net entanglement, and skin injuries were also fairly common incidents.

3. What data is available that allows these safety outcomes to be assessed globally for the aquaculture industry?

Given there is a reporting bias to countries where aquaculture OH&S issues would be expected to be reasonably managed, it is hypothesised that the FAO figures would actually be a significant underestimate of the prevalence of many occupational injuries and diseases in the global aquaculture industry. The granularity of OH&S reporting systems in many countries does not allow data extrapolation – at best, reporting of incidents in the aquaculture industry are aggregated within agriculture / fisheries / forestry-type reported data. Types of accidents / incidents are not reported sufficiently and there is no standardised approach for reporting of aquaculture OH&S incidents. The lack of management / regulation governing small-scale aquaculture operations, mean there are big uncertainties on the exposure of workers on smaller-scale farms to OH&S hazards.

One approach may be to investigate data sets such as use of chemicals on farms. In their interview-based study, Ali et al (2016) in Bangladesh identified a large number of compounds that are currently in use, and that require further regulation and evaluation regarding their potential environmental and human health impacts [14], as already done in most developed countries. This may give some insight of the likely risk exposure profile for farm workers in these regions and indication of the focus for interventions.

4. **What are the leading indicators of safety in related areas (including traditional industries identified in 1., and what interventions have been demonstrated to improve safety that might be applicable to the aquaculture industry as it develops?**

   A number of indicators were identified that likely relate to the management of OH&S risks in the aquaculture sector: country governance, country regulations and implementation / enforcement, scale and level of organisation of sector (formal versus informal), type of operation, social-cultural factors, extent of third-party certification, and the hazards associated with the natural environment. These indicators have been identified from a review of primary studies and country level analysis. However, the relative importance of each in determining OH&S outcomes will still need to be fully explored.

   Finally, interventions relating to many of these indicators were discussed. In LMICs, most aquaculture workers are from vulnerable populations and are precariously employed, with low emphasis paid on the protection and promotion of these workers' health [3]. In many countries, improvements need to be made to the legislative and institutional basis for the management of OH&S risks. At a business level, targeted training will be required to raise the awareness of occupational hazards amongst workers and managers.

Recommendations

The research identifies stark differences in the availability of OH&S information associated with aquaculture across geographic regions.

Some regions, typified by a higher development status, have progressed more comprehensive OH&S systems (including policy, regulation, reporting and accountability) applicable across all work sectors and some have progressed implementing and reporting tools specific to their aquaculture sectors. Other regions have far less mature and identifiable frameworks and scant or no available data for evaluating the performance of OH&S in aquaculture. Where reporting is evident, data is often amalgamated and not sector specific.

The lack of comparative data indicates a clear need for a comprehensive framework for evaluating and reporting the current status of OH&S in aquaculture that can be applied consistently at country, regional and / or aquaculture systems level. Its development would require an international approach with multi-stakeholder and disciplinary inputs (government, industry, institutional, NGO, academia, etc.). It would need to:

- define and agree universal standards and metrics. This review identifies some potential indicators that influence OH&S performance at country and sector level (e.g. governance, policy, pace of aquaculture development, industrialisation, environmental setting). These would need further development and consensus building across the group, co-ordinated by an independent organisation

- create a mechanism for its application and reporting. The approach would need a defined process to ensure independence, credibility, and repeatability and build upon current established standards for consistency in data collection (e.g. UN ILO); and
- establish endorsement from the major international organisations associated with labour and aquaculture (e.g. UN ILO, FAO, WHO).

A framework is essential in the creation of an evidence base collection system. It can operate as a benchmark process and allow OH&S performance to be measured consistently. Overtime, it would allow the impact and success of intervention programmes to be measured against standardised performance metrics for OH&S.

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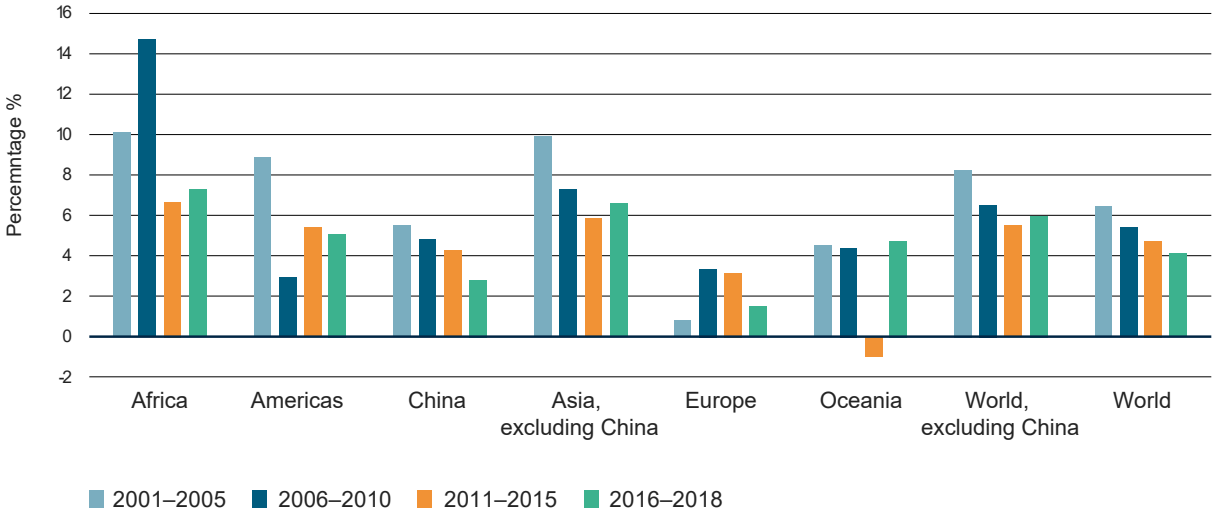
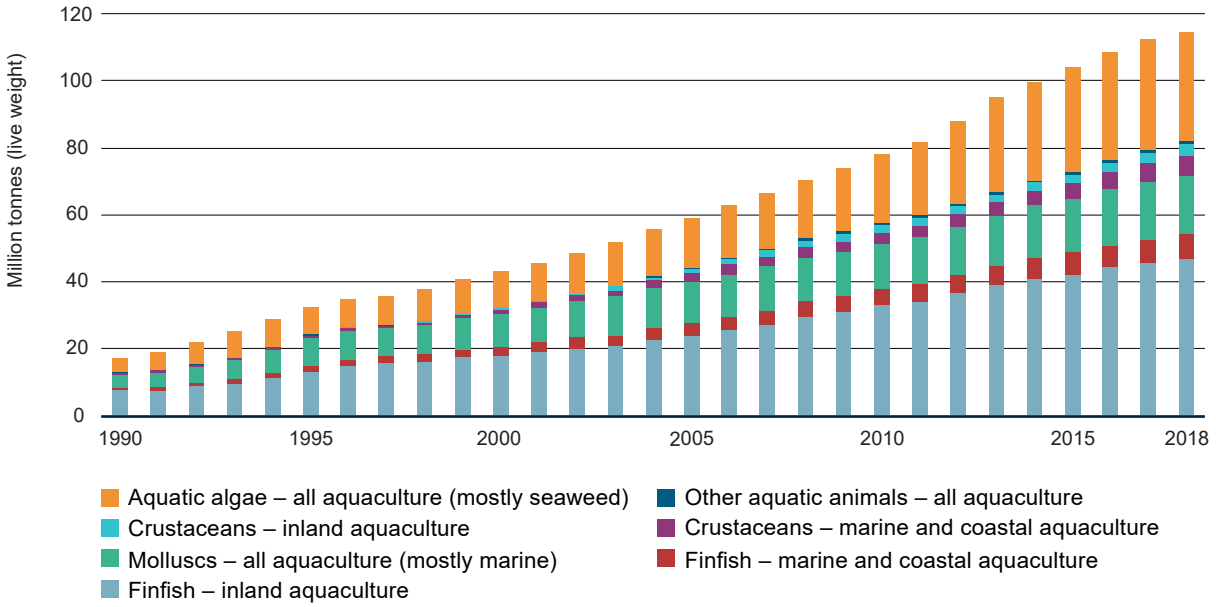
Annex 1 – FAO global aquaculture production charts

Annual growth rate of aquaculture fish production quantity in the new millennium [2]



World aquaculture production of aquatic animals and algae, 1990–2018 [2]



Annex 2 –Main aquaculture species (FAO 2020)

Major species produced in world aquaculture, [2]

	2010	2012	2014	2016	2018	2018 share
	(thousand tonnes)					(percentage)
Finfish						
Grass carp, *Ctenopharyngodon idellus*	4 213.1	4 590.9	5 039.8	5 444.5	5 704.0	10.5
Silver carp, *Hypophthalmichthys molitrix*	3 972.0	3 863.8	4 575.4	4 717.0	4 788.5	8.8
Nile tilapia, *Oreochromis niloticus*	2 657.7	3 342.2	3 758.4	4 165.0	4 525.4	8.3
Common carp, *Cyprinus carpio*	3 331.0	3 493.9	3 866.3	4 054.7	4 189.5	7.7
Bighead carp, *Hypophthalmichthys nobilis*	2 496.9	2 646.4	2 957.6	3 161.5	3 143.7	5.8
Catla, *Catla catla*	2 526.4	2 260.6	2 269.4	2 509.4	3 041.3	5.6
Carassius spp.	2 137.8	2 232.6	2 511.9	2 726.7	2 772.3	5.1
Freshwater fishes nei[1], Osteichthyes	1 355.9	1 857.4	1 983.5	2 582.0	2 545.1	4.7
Atlantic salmon, *Salmo salar*	1 437.1	2 074.4	2 348.1	2 247.3	2 435.9	4.5
Striped catfish, *Pangasianodon hypophthalmus*	1 749.4	1 985.4	2 036.8	2 191.7	2 359.5	4.3
Roho labeo, *Labeo rohita*	1 133.2	1 566.0	1 670.2	1 842.7	2 016.8	3.7
Milkfish, *Chanos chanos*	808.6	943.3	1 041.4	1 194.8	1 327.2	2.4
Torpedo-shaped catfishes nei, *Clarias* spp.	343.3	540.8	867.0	961.7	1 245.3	2.3
Tilapias nei, *Oreochromis* (=Tilapia) spp.	472.5	693.4	960.8	972.6	1 030.0	1.9
Rainbow trout, *Oncorhynchus mykiss*	752.4	882.1	794.9	832.1	848.1	1.6
Wuchang bream, *Megalobrama amblycephala*	629.2	642.8	710.3	858.4	783.5	1.4
Marine fishes nei, Osteichthyes	467.7	567.2	661.0	688.3	767.5	1.4
Black carp, *Mylopharyngodon piceus*	409.5	450.9	505.7	680.0	691.5	1.3
Cyprinids nei, Cyprinidae	639.8	601.1	628.0	596.1	654.1	1.2
Yellow catfish, *Pelteobagrus fulvidraco*	177.8	233.7	302.7	434.4	509.6	0.9
Other finfishes	6 033.9	6 869.3	7 730.0	8 217.1	8 900.2	16.4
Finfish total	**37 745.1**	**42 338.2**	**47 219.1**	**51 078.0**	**54 279.0**	**100**
Crustaceans						
Whiteleg shrimp, *Penaeus vannamei*	2 648.5	3 144.9	3 595.7	4 126.0	4 966.2	52.9
Red swamp crawfish, *Procambarus clarkii*	596.3	548.7	659.3	894.7	1 711.3	18.2
Chinese mitten crab, *Eriocheir sinensis*	572.4	650.7	722.7	748.8	757.0	8.1
Giant tiger prawn, *Penaeus monodon*	562.9	669.3	701.8	705.9	750.6	8.0
Oriental river prawn, *Macrobrachium nipponense*	193.1	200.0	204.1	245.0	237.1	2.5
Giant river prawn, *Macrobrachium rosenbergii*	217.7	216.2	233.7	238.4	234.4	2.5
Other crustaceans	687.9	586.1	631.1	717.3	729.9	7.8
Crustaceans total	**5 478.8**	**6 016.0**	**6 748.3**	**7 676.1**	**9 386.5**	**100**

[1] nei = not elsewhere included – all cases.

Table continued overleaf

Major species produced in world aquaculture, continued [2]

	2010	2012	2014	2016	2018	2018 share
	(thousand tonnes)					(percentage)
Molluscs						
Cupped oysters nei[1], *Crassostrea* spp.	3 570.7	3 807.4	4 181.6	4 690.8	5 171.1	29.5
Japanese carpet shell, *Ruditapes philippinarum*	3 500.2	3 618.7	3 838.6	4 175.8	4 139.2	23.6
Scallops nei, Pectinidae	1 366.6	1 360.9	1 576.5	1 849.9	1 918.0	11.0
Sea mussels nei, Mytilidae	871.4	937.1	992.9	1 085.4	1 205.1	6.9
Marine molluscs nei, Mollusca	556.3	993.9	1 035.4	1 118.1	1 056.4	6.0
Constricted tagelus, *Sinonovacula constricta*	693.3	690.4	752.0	799.3	852.9	4.9
Pacific cupped oyster, *Crassostrea gigas*	640.7	609.1	623.6	573.8	643.5	3.7
Blood cockle, *Anadara granosa*	456.7	378.2	434.2	430.4	433.4	2.5
Chilean mussel, *Mytilus chilensis*	221.5	244.1	238.1	300.6	365.6	2.1
Other molluscs	1 850.8	1 706.7	2 035.0	1 816.0	1 725.8	9.9
Molluscs total	**13 728.3**	**14 346.7**	**15 707.8**	**16 840.1**	**17 510.9**	**100**
Other animals						
Chinese softshell turtle, *Trionyx sinensis*	261.1	306.3	313.6	335.4	320.9	34.9
Japanese sea cucumber,*Apostichopus japonicus*	126.6	163.9	193.0	204.7	176.8	19.2
Aquatic invertebrates nei, Invertebrata	215.5	118.4	103.6	88.0	120.9	13.2
Frogs, *Rana* spp.	79.6	78.2	87.9	90.7	107.3	11.7
Other miscellaneous animals	109.1	112.3	132.7	190.8	192.7	21.0
Other animals total	**791.8**	**779.2**	**830.7**	**909.6**	**918.6**	**100**

[1] nei = not elsewhere included – all cases.

Annex 3 – List of stakeholders interviewed

Sector	Organisation	Contact	Interview method
Fish farm manager	African Blue Tilapia, Kenya	Dr Judith Brown	Personal experience
Aquaculture research scientist	CSIR-water research institute, Ghana	Emmanuel Mensah	LinkedIn messaging
Salmon service provider	ROV Systems, Chile	Luis Martinez	Call
Third-party certification – standards body	GAA	Avery Siciliano	Email
Certification body	Global Trust	Fergal Guilfoyle, Jose Llorente, Paul Casburn (aquaculture auditors)	Call
NGO	Fish Safety Foundation	Dr Kate Pike	Call
Scientific researcher	Health and Technological Innovation in Aquaculture Department of Agricultural Diagnosis and Research – DDPA, Chile	Dr Lissandra Souto Cavalli	Call
Intergovernmental	ILO	Yuka Ujita	Call
Social development consultant	Independent consultant	Birgitte Poulson	Call
Academic	Memorial University	Barbara Neis	Call
		Courtney Ochs	Call
Public body	Seafish	Lee Cocker	Call
Academic	University of Cape Town	Dorothy Ngajilo	Call
		Mohamed Jeebhay	Email
Academic	University of Stirling, UK	Professor Andrew Watterson,	Email
Academic	University of Zambia	Eva Nambeye	Call

Annex 4 – Overview of third-party certification schemes

There are several international programmes and standards bodies that operate third-party certification schemes for aquaculture. These organisations set best practice and sustainable criteria. Aquaculture establishments that wish to demonstrate that they meet these 'higher standards' of practice can adopt these criteria and become recognised through third-party certification, assessed by independent aquaculture auditors. Certification often means a greater level of recognition from discerning buyers who prefer these supplies above others. Three leading schemes in aquaculture are:

- Global Seafood Alliance (GSA): Best Aquaculture Practice Standards
- Aquaculture Stewardship Council (ASC) Programme for Responsible Aquaculture; and
- Global GAP – Good Aquaculture Practice Standards.

These three programmes have set or adopted standards based on internationally recognised principles of social welfare and OH&S in the aquaculture workplace. The core principles include those set by the ILO and international standards for social accountability and for OH&S. These include prohibiting the use of child labour or any form of forced labour, health and safety in the workplace and fair and equitable working conditions with regulated working hours that allow for sufficient periods of physical and psychosocial rest. These could be considered as fundamental to any workplace setting and their implementation could be considered prerequisites to the provisioning of effective occupational health and safety in aquaculture workplace settings.

An absence of these fundamental conditions is likely to hamper any interventions for improving OH&S. All three organisations set standards for OH&S training, worker instruction, provisioning of PPE, reporting of incidences and interventions (e.g. risk assessment) and responses (e.g. first aid) for the prevention and mitigation, of incidents and accidents.

The Best Aquaculture Practices Farm Standard Issue 3.0: 01 March 2021[1] can be used by way of example. Criteria are specified across a number of areas specific to 'Pillar 2, Social Accountability', including; legal obligations, community relations, worker rights and employee relations, wages, working hours, forced or bonded labour, child and young labour, hiring terms, contracts, discipline, discrimination, freedom of association and worker health and safety.

There are 14 clauses specific to the worker health and safety such as:

- 2.4.9: The farm shall identify, prevent, eliminate, or minimize any workplace health and safety hazards. This includes a requirement for documenting incidents, and investigations of accidents and their cause and correction; and
- 2.53: Personal protective gear and equipment (e.g. eye protection for welding, gloves for shop work, boots for wet areas, life jackets on boats) in good working order and in alignment with local laws and work.

The standard overall notes that workers should be provided with:

- knowledge and skills needed to do their work safely and avoid creating hazards that could place themselves or others at risk
- awareness and understanding of workplace hazards and how to identify, report, and control them; and
- specialised training when their work involves unique hazards.

1 https://www.bapcertification.org/Standards

Similarly, ASC covers a wide range of social criteria, with requirements in its standards on worker rights, forced labour, child labour, community engagement, discrimination and harassment, access to grievance mechanisms, transparent contracting and wage requirements, working hours and conditions, freedom of association and collective bargaining, and respect for the rights of indigenous communities.

The standards also include requirements around health and safety, requiring a health and safety risk assessment, training for workers in health and safety, PPE for workers, and recording of any violations. ASC standards also work for remediation in this area, requiring that corrective actions are taken wherever a violation occurs, and requiring insurance for 100% of worker costs in a job-related accident or injury when not covered by law.

Certification to the BAP and ASC (and other international third-party standards) requires that the farm adopts the requirements and receives an annual audit from an approved certification body, with specialist auditors, trained in the standard's requirements. Non-conformances (NCs) are raised where compliance falls below acceptable, which the farm must address with corrective action to remain certified.

Third-party standards are adopted for many reasons (improvements in practice, support regulatory compliance, demonstrate to internal stakeholders / shareholders), and are most often adopted to gain access to higher valued markets. They can serve as important tools for improving farm practice and some of the programmes have active improver mechanisms that serve to engage aquaculture sectors in the improvement journey.

The vast majority of certifications in Chile and Norway are salmon farm sites. China certifications are broadly tilapia, shrimp, and bivalve shellfish. The Bangladeshi and Guatemala certifications are shrimp farms.

Table of certified aquaculture farms (all types) May 24th 2021

Standard	Bangladesh	Chile	China	Ghana	Guatemala	Kenya	Norway
ASC	2	305	29	0	1	0	325
BAP	5	360	105	0	3	0	2

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