Occupational safety in aquaculture – Part 2: Fatalities in Norway 1982-2015

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Abstract

This article presents an overview of reported fatalities in the Norwegian aquaculture industry focusing on the production of Atlantic salmon and trout, which dominate the fish farming industry in Norway. The data on fatalities from 1982-2015 are registered by SINTEF Ocean, which is the only data source available. The fatality data set includes information on the incidents leading to fatalities, activities conducted at the time of fatalities, and the time of year the fatalities were registered. The article discusses the fatality trends in light of the characteristics and changes in the Norwegian fish farming industry during the last three decades. This provides useful information for determining the most important current safety challenges and for developing efficient safety management in aquaculture.

Keywords

Aquaculture, risk, occupational safety, occupational fatalities

1.0 Introduction

The Norwegian aquaculture industry has grown since the 70s to become one of the most important industries in the country, and Norway is now the dominant producer and exporter of Atlantic salmon worldwide [1]. Aquaculture production and fish farming is an important contributor to satisfying the need for healthy, sustainable food for a growing world population [2]. In 2010, aquaculture contributed to 47 percent of the fishery output for human consumption [3], and the number is expected to grow [4]. More aquaculture production is related to the wild catch having reached a plateau and the amount of sustainable catch is unlikely to increase [5].

The majority of fish farm production (grow-out) is set in the fjords along the Norwegian coastline. Traditionally, sites have been chosen because they have been sheltered from the stronger wind, waves and currents that are experienced further ashore. However, the establishment of more fish farms has increased the competition over the most feasible localities, and improved production environments are sought [6, 7]. This trend is continuing and efforts are put into investigating the opportunities for exposed or offshore fish farming [8]. The work environment for aquaculture operators is already highly influenced by the unpredictable and uncontrollable forces of nature [9]. A large part of the work conducted is manual labor aided by equipment such as hooks and knives, but also heavier machinery like cranes and winches are used in important operations. With the shift towards more exposed

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production, the workplace will become even more hazardous, and it is paramount that the industry has a solid understanding of the hazards and risks in the workplace so that suitable prevention measures can be implemented.

The production of farmed salmon and trout consists of three main phases: juvenile production, grow-out production and processing. Juvenile production occurs on land, both indoors and outdoors, with fish contained in smolt tubs with fresh water. Grow-out production is mainly sea-based in net cages, suspended from floaters or from individual circular plastic collars (see the related article [10] for more details on aquaculture production in Norway).

The production methods used today expose the operators to many hazards during the workday. Comparative studies show that the Norwegian aquaculture industry has the second highest incident rates for fatalities, after fisheries, but before agriculture, the offshore oil and gas supply fleet and the construction industry [11]. Despite the fact that aquaculture operators have one of the most dangerous professions in Norway, only limited research efforts have been made towards improving occupational safety in this industry, and statistics and in-depth analysis of occupational fatalities are missing. Structural properties of marine fish farms, both nets and cages, have been more thoroughly investigated than occupational safety [12-15]. Structural analysis has been especially important in relation to preventing the escape of fish from net cages [16], which has received a wide focus because of the negative implications from interactions with wild salmon [17, 18]. Due to the focus on fish escapes, and the implementation of improved technical standards, there is a decrease in the total loss of fish farms due to structural inadequacies [16, 19]. Nevertheless, even though these efforts may be beneficial for the operators on fish farms, occupational safety as such has not been the focus of these studies.

Critical hazardous work tasks in fish farming were identified in a research project related to exposed fish farming; examples include removal of dead fish, inspections and maintenance, lice counting, well boat operations and operations involving cranes [9]. In these operations, hazard sources can be of a mechanical type (moving cranes, rotating equipment, sharp knives and stability problems), environmental (harsh weather conditions) or human related (stress). A previous study on health, safety and environment (HSE) in aquaculture identified incidents involving falling, pinching/perforation, impacts and crushing as the largest contributors to injuries in the industry [20].

Studies on organizational and human factors related to safety aspects of Norwegian fish farming [21-23] show that operators on fish farms to a large extent are left to themselves when making everyday decisions. Proper decision support and clearly defined responsibilities are crucial with the rapid growth of the industry. Fish farm installations have increased in size and complexity, the equipment and expertise needed to perform operations have changed, and more specialized external service providers are now a part of normal operations. A study of causes, risks and organizational aspects of escape events shows that human factors contributing to escape can be linked to human interaction with technology, the physical work environment, workload, work pressure, training, skill, experience, co-operation, communication and safety management [21]. These factors have previously also been linked to occupational safety. Investigations of fatal accidents in Norwegian aquaculture show that organizational factors have been important contributors to the accidents [24, 25]. The investigation reports conclude that the aquaculture companies in charge had not carried out and documented adequate risk assessments of the operations and the equipment involved. In addition, the aquaculture companies were not able to document sufficient training of the operators. In addition, conflicting objectives with regard to the prioritization of personal safety and safety of the fish (including prevention of escape) can in specific situations lead to increased occupational risk during operations.

The objective of this article is to provide a quantified overview of fatalities in the aquaculture industry in Norway, and contribute to an improved understanding of the causal factors. The results can be used for risk assessments in the companies, and for allocating resources to mitigate hazardous events, both in the private and in the public sector. The results should also be valuable for future research regarding safety in the aquaculture industry. While this article focuses on fatalities, a separate sister article (Holen et al., 2016a, submitted) addresses injuries in Norwegian aquaculture.

The structure of the article is as follows: Section 2 describes the data material used, Section 3 presents results, and Sections 4 and 5 include the discussions and conclusions.

2.0 Methodology and data

The data on fatalities from the aquaculture industry presented in this article are collected from a database at SINTEF Ocean. The registered fatalities are based on extensive research using networks and media reporting on fatalities in the fish farming industry.

Fatality rates per year are shown in Table 1. These are based on the number of person-years in the aquaculture industry (see Table 1 for the time period of available data). Person-years is found by dividing the total number of hours worked in the industry by one person-year, which is defined as 1750 hours [26, 27]. The fatality rate is then found by dividing the number of fatalities by the number of person-years worked in one specific year. The number of person-years steadily increased from 1994 to 2014.

SINTEF has registered 34 fatalities for the period 1982–2015 [28]. In the following subsections, the results are presented in terms of number of yearly and periodical fatalities, place of fatality, incident leading to fatality, work operations conducted at the time of fatality, and age and month of reported injuries. The population at risk includes personnel in all production phases, which, in addition to sea-based fish farming and land-based fish farming, includes fish and fodder transportation (by sea and land) and fish processing. In addition, fatalities related to shell farming have been included in the statistics.

Data on person-years, and hence fatality rate, are not available for the total period of available data on fatalities. Rates are thus not provided for other purposes than in Table 1 and Figure 1.

3.0 Results of data analysis

3.1 Annual overview of fatalities

From 2004 to 2015, the number of person-years in the Norwegian aquaculture industry steadily increased (see Table 1). Despite this, the number of fatalities has decreased since a peak in the late 80s. Also, the fatality rates per 10,000 person-years have decreased since the 1990s. In the 1990s, the highest fatality rates in aquaculture were on a level with fisheries, which had a fatality rate per 10,000 person-years ranging from 4.9 to 23.8 in the years 1990-2000 [11]. Fisheries is the industry with the highest fatality rates among comparable industries [11]. The three year rolling average also shows that

that since 2000 the fatality rates have remained stable, with the exception of the year 2012, when the capsizing of a work vessel resulted in two passenger fatalities [24], (see Fig. 1).

Table 1. Person-years, number of fatalities and fatality rates per 10,000 person-years, 1982–2015 [26, 28]

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Person-years	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2987	3264	3089	2930	2787
Fatalities	1	0	0	0	0	2	1	5	2	1	0	0	1	3	1	0	3
Rate per 10,000 person-years	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.35	9.19	3.24	0	10.76

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Person-years	3070	3052	3070	3205	3139	2919	2953	3203	3369	3659	3764	4063	4249	4387	4726	4910	5182
Fatalities	3	2	0	0	1	0	1	0	1	0	0	1	0	3	0	0	1
Rate per 10,000 person-years	9.77	6.55	0	0	3.19	0	3.39	0	2.97	0	0	2.46	0	6.84	0	0	2.00

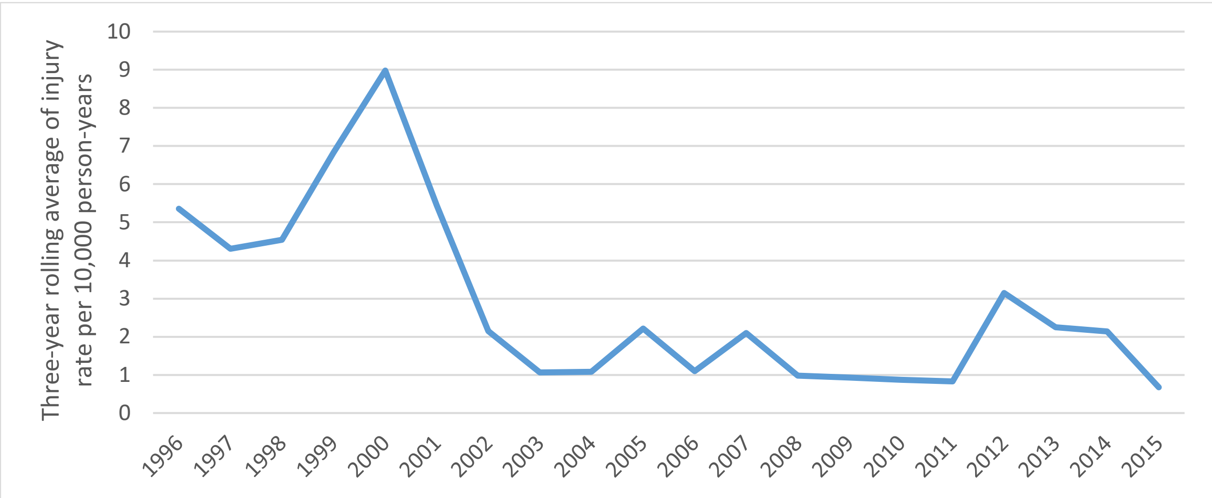

Fig. 1. Three-year rolling average of injury rate per 10,000 person-years

3.2 Place of fatalities

The majority (60%) of the accidents happened on board *work vessels* (see Table 2). The category *work vessels* includes a range of different vessels, as there has been a development in the technology and design of these vessels since the beginning of the 1980s. The type of vessel used in the earlier years of fish farming can be characterized as small open leisure boats, and also small fishing vessels originally used for fishing were used for fish farm purposes. One type of boat seemed to be used for several purposes, such as transport of fodder and equipment and during operations. Larger, purpose-built vessels with installed equipment, such as cranes and capstans, have been more commonly used since 2000. Fodder is now to a larger extent transported directly to the fish farm by the fodder vendor. Twelve of the fatalities happened during *transport,* while *work operations* led to seven fatalities, and one fatality happened during a maintenance operation (see Fig. 2).

The fish farm itself is the second most exposed place for fatalities (21% of fatalities), where the accidents are related to the operations at the localities. Three of the seven fatalities on fish farms happened in relation to *diving* activities, where the divers were entangled during work, such as collecting dead fish or performing maintenance on the net cage. The last four fatalities occurred due to a *blow from an object* during *maintenance*, *crush* in relation to work on a pellet machine, *man overboard* during *maintenance* and a *work operation*.

Fish transfer vessels are used to transfer live fish in wells. The two fatalities on fish transfer vessels happened during *transport* and led to one *man overboard* fatality and one *loss of vessel* fatality.

Place of fatalities	Number of fatalities
Work vessel	20
Fish farm	7
Fish transfer vessel	2
Process facility	1
Smolt facility	1
Truck	1
Pram	1

Table 2. Place of fatalities in Norwegian aquaculture 1982–2015 [28].

3.2 Fatal incidents and work operations

In Fig. 2, the incidents leading to fatalities, and operations conducted at the time, are presented. *Loss of vessel* is the main cause of fatal incidents and accounts for 15 of the fatalities (45%). Twelve of the *loss of vessel* incidents happened in relation to *transport* (see also Fig. 3).

Blow from an object/crush fatalities (18%) are mainly related to *work operations* on work vessels, due to being crushed by a crane, or to a blow from an object released from tension.

Man overboard fatalities (15%) mainly occurred in relation to *work operations* during activities such as loading of fish and foddering, and falls from vessels during *transport*.

Three of the four diving fatalities occurred during diving operations at fish farms. The fourth diving fatality happened when maintenance work was being conducted in piping on a land-based smolt facility, and the diver became stuck in the piping at an outlet. This is also the only registered fatality in land-based fish farming.

Fig. 3 shows the types of operations being conducted at the time of fatalities for different time periods. The number of accidents per decade decreased by one third in the 2000s compared to the two previous decades. Even though the last column in Fig. 3 presents the fatalities for only three years, 2012–2015, one more fatality than the previous decade is registered. The figure shows that *transportation* was a major contributor to accidents before 1992. These fatalities happened due to *loss of vessel*, and in 1989, two incidents led to five fatalities. Both these incidents concern small fishing vessels, which capsized in harsh weather conditions.

Fatalities in relation to *work operations* have mainly happened since 1992, and have led to *blow from an object/crushing* and *man overboard* fatalities, as mentioned above. In addition, one major *loss of* *vessel* incident led to two fatalities in 2012 when a capsizing occurred due to misuse of a crane in harsh weather conditions (cf. Section 3.1).

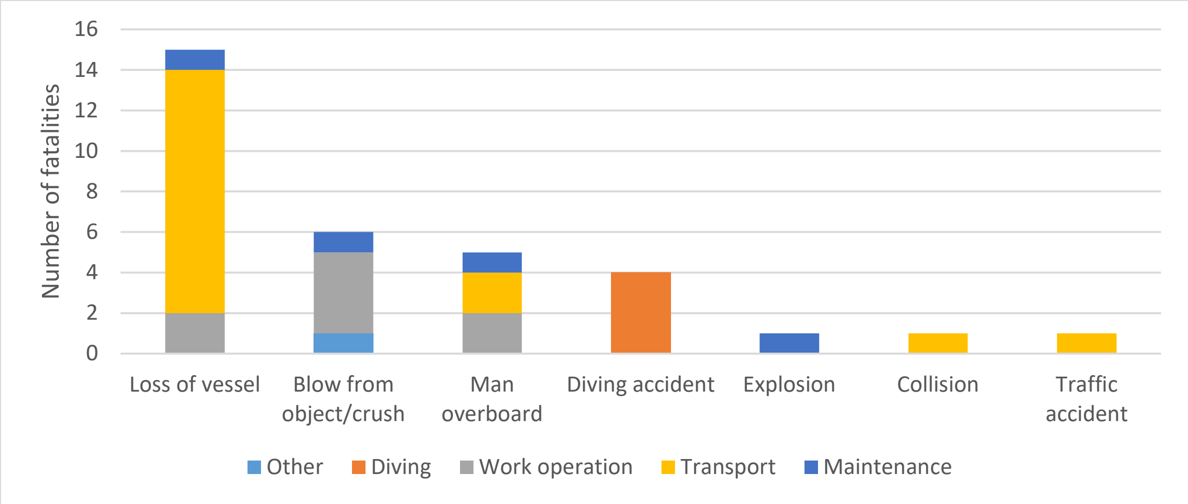

Fig. 2. Incidents leading to fatalities, and operations conducted at the time, in Norwegian aquaculture 1982–2015 [28].

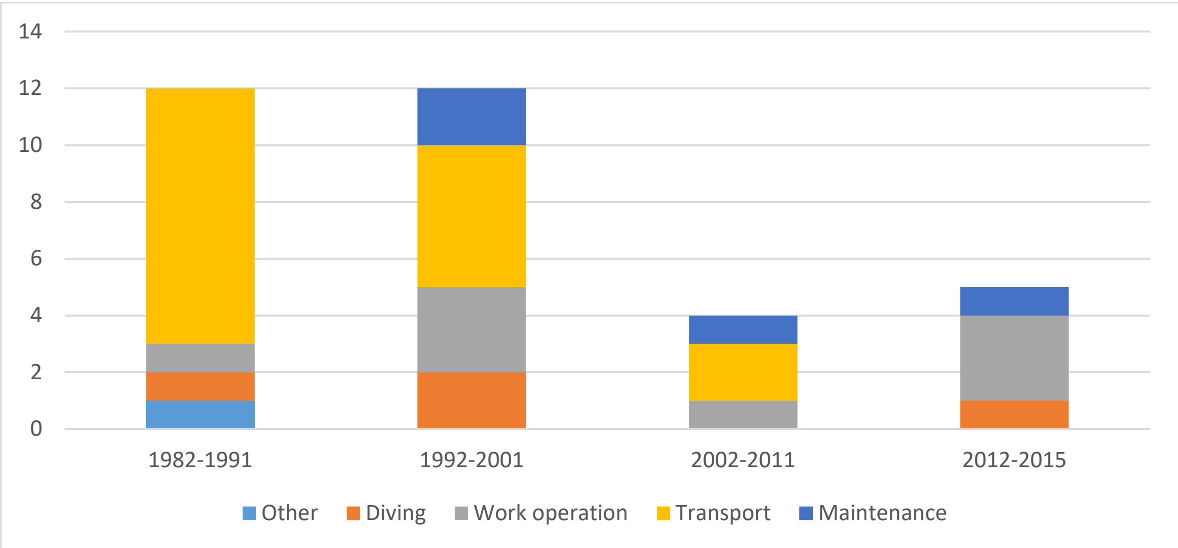

Fig. 3. Fatalities in types of operations in Norwegian aquaculture 1982–2015 [28].

3.3 Age

Table 3 shows the number of fatalities in Norwegian aquaculture for the specified age groups. Most fatalities occurred in the 40-54 years age group. The three fatalities in the two youngest age groups included two students employed as seasonal workers on fish farms, while the third fatality was one of the passengers who drowned in 2012 (cf. Section 3.1).

Age group	Number of fatalities
0-14	2
15-19	1
20-24	3
25-39	6
40-54	15
55-67	6

Table 3. Fatalities for each age group in Norwegian aquaculture 1982–2015 [28].

3. 4 Fatality by month

The two months with the highest number of fatalities are January and July (see Fig. 5). In January, six out of seven fatalities occurred in relation to *loss of vessel*. January is a month when storms are common, and in five of the fatalities, harsh weather conditions are mentioned as a factor contributing to the fatality. The fatalities in July occurred in relation to *diving*, *work operations* and *loss of vessel*, and two of the fatalities in June and July were young seasonal workers.

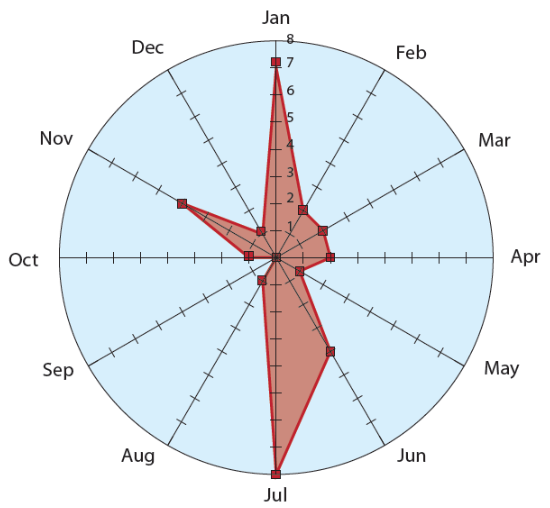

Fig. 5. Time of year regarding fatalities in Norwegian aquaculture 1982–2015 [28].

4. 0 Discussion

Underreporting is a known problem in many official accident-reporting systems [29, 30]. The data set from SINTEF Ocean on fatalities is most likely more complete than the registries of occupational injuries (see the related article [10]). The data set used in this article is based on information from contacts in an extensive industry network, in addition to newspaper articles. The data have also been checked against occupational accident registration by the authorities. In certain cases, fatalities have been included in this registry and not in the authorities' registries, e.g., because they have happened in relation to aquaculture activities, though not involving personnel employed by an aquaculture company.

4.1 Place of fatality, critical operations and incidents leading to fatalities

From 1982 to 2001, the majority of the fatal accidents occurred in relation to loss of vessel during transport to and from the aquaculture facilities, but the number of transport-related fatalities has decreased since the beginning of the 2000s. Many of the vessels involved in these accidents were not specialized or designed for the types of operations carried out in the fish farming industry. The main contributing causes to loss of vessel were overloading and harsh weather conditions. All the fatalities that happened in harsh weather conditions occurred from drowning due to loss of vessel, either during transport or work operations

Fewer fatalities have happened in relation to transport at sea in the last two decades, and work operations have taken over as the principal contributing cause leading to fatalities. The incidents leading to most fatalities were blow from an object/crushing and loss of vessel. Work operations involving the use of cranes and capstans are identified as critical by operators on fish farms [21, 31], and is also a contributing cause to occupational injuries [10]. Cranes and capstans are used in daily operations, such as the removal of dead fish, and in less frequent, but more resource-demanding and complex operations, such as preparations for delousing with tarpaulins and changing of nets. The large forces in play during work operations and the sometimes unpredictable forces from the environment should make crane operations an area of focus in safety management and risk assessments. An important aspect in this regard is making sure that cranes are only used according to the limitations of the work vessels where they are installed, and that all hazards associated with work operations are assessed and understood by operators. Inadequate consideration of these issues has been pointed out as a factor contributing to fatalities in fish farming in official investigations in recent years [24, 25].

Fatalities occurring in relation to both transportation and work operations have mainly happened on work vessels. In view of the types of vessels used, and the considerable amount of time used on work vessels for transportation and during fish farm operations, this does not seem like an unreasonable outcome. Even though loss of vessel during transport has decreased in the last decade, the work vessel is still the location of over half of the fatalities, and a focus on the safety of these vessels should be maintained. There has been a development in the types of vessels used in the fish farming industry. When the fish farming industry was still a small-scale, often family-driven industry, the vessels used were those available at the time such as fishing vessels or small leisure boats. The vessels were used for all purposes, such as transportation of fodder, equipment or people to the fish farms. With the growth in the industry, the fish farms are located further offshore and net cages are bigger. A need for seaworthy and specialized vessels with larger margins with regard to loading capacity and capabilities and stability thus emerged. The small-hulled vessels earlier used in the 1980s and 1990s could not sustain the need for heavier cranes, and twin-hulled vessels that could resist heeling in crane operations were built. Twin-hulled vessels are still extensively used in the fish farming industry, though these vessels have proven to be somewhat difficult to maneuver in the weather conditions seen at less sheltered fish farms. Larger one-hulled vessels are thus now being built for fish farm operations. The development of work vessel regulation is further discussed in Section 4.3.2.

Fish farms are the location of the second highest number of fatalities, and diving activities are the largest contributor. As diving is a service in need of special competence, diving services are largely performed by subcontractors to the fish farmers.

Most of the work operations with fatal outcomes are performed from work vessels on the fish farms, in activities such as feeding and maintenance. Covered walkways on which the operators move when they are working are increasingly being implemented, which improves safety. These are more stable than the uncovered walkways previously used, and could prevent man overboard incidents from the net cage and when operators are moving in between the vessel and the net cage.

Personal protection equipment (PPE) is an essential safety measure for the workers at sea. The information in the provided register of fatal accidents is not complete. In only four cases is appropriate PPE, like floating vests/suits, registered as being used when the fatal accident happened. In ten of the fatalities, it is registered that an appropriate PPE was not employed. Though PPE is an important mitigating measure, it is only one of the possible approaches to safe operations, and in some cases, it is not sufficient as a sole protection measure. Thus, other physical preventive measures, such as safety zones, automatic stop mechanisms on crane force and railings on the work vessels, can decrease the consequences of accidents in fish farming and must be assessed as hazard-mitigating efforts.

4.2 Seasonal changes

The distributions over time of year of fatalities show an increase of injuries in July and during the winter months of November and January. July has the highest number of fatalities. During the summer months, temporary personnel are hired to replace and assist the permanent employees. In addition, due to regulations, delousing is frequently performed during the summer months when water temperatures provide good living conditions for the lice. Delousing is also considered a high-risk operation in relation to escape incidents [31]. A higher number of less experienced employees and more complex work operations might lead to higher risk for occupational accidents. The winter months have harsher weather conditions and shorter daylight periods, which may explain the seasonal peak during these months.

Fig. 6 shows incidents of escape of salmon and trout in Norway, which is one of the major environmental risk issues on fish farms. The statistics show that in the autumn and winter months there is a larger number of escape events. The escape numbers have been linked to structural failures that happen in relation to environmental forces, such as high wind, waves and current (Jensen et al., 2010). Harsh weather conditions thus seem to be an influencing factor for both occupational injuries and fatalities, as well as the escape of salmon. The prevention of incidents related to escape and occupational safety has been found to bear similarities (Thorvaldsen et al., 2015).

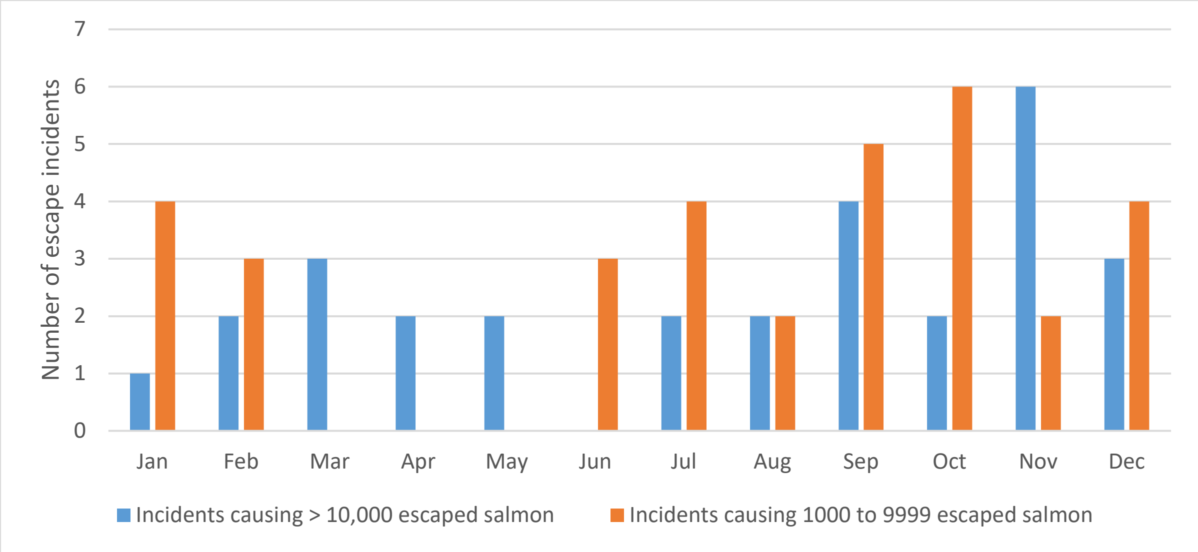

Fig. 6. Escape incidents per month 2008–2013, salmon and trout, Norway [32]

4.3 The trend of fatalities

It has not been possible to obtain fatality rates for the whole period of available data and thus only the number of fatalities is presented (cf. Section 2.0). This makes a direct comparison to occupational fatality statistics in other industries difficult. However, fatality rates per 10,000 person-years is presented for 1994-2015, and these have remained stable since 2000, except a jump in 2012 (cf. Section 3.1).

The occurrence of fatalities in the fish farming industry are influenced by certification in relation to standards on work environment and safety, development of technology, a restructured industry and the introduction of new regulations. This is further discussed in the subsequent sections (regulations are further discussed in the related article [10]).

4.3.1 Certification

The increased focus on accredited certifications may have had a positive effect on safety in Norwegian aquaculture. A study of the impact of management system certifications on safety management found that certified organizations have significantly better safety management practices and safety behavior than noncertified organizations [33]. A range of different global certifications have been implemented in the fish farming industry worldwide, regarding issues, such as food safety, animal health, environment, social and ethical issues, and food quality [34]. To be certified, the company must prove compliance with a certain standard through an audit performed by an, often third party, independent certifying body [35]. The market for the sale of salmon is international, and demands for a safe, sustainable product are pressing. Retailers, such as supermarkets, can be important drivers for product modifications when imposing strict quality requirements [36]. The European market (especially Holland, France, the UK and Germany) is concerned with compliance to the Aquaculture Standard of the GLOBALG.A.P. [34]. This standard focuses on safe and sustainable production of consumer products, and covers sustainability criteria related to legal compliance, food safety, worker occupational health and safety, animal welfare, and environmental and ecological care. Other standards that are commonly used for ensuring best practice work in fish farming are the ISO 9000 and 14000 standards [37, 38], which are concerned with quality and environmental management, respectively.

4.3.2 Technical regulations

The technical equipment in the fish farming industry has changed, due to larger production units and quantities. Performing regular operations, such as the handling of nets and fish, requires more specialized equipment and vessels. When the production units first started to grow, experimenting with standard equipment was necessary to find suitable ways of performing the operations. Today, vendors are delivering specially designed equipment to fulfill the specific needs of fish farming. The fish farmers themselves are driving forces of the technology development in co-operation with suppliers and contractors.

The length of work vessels on fish farms have traditionally been less than 15 meters [39]. This can be attributed to the regulations, which up until 2015 stated that special certificates were needed for larger vessels, with a different set of approval rules. Fish farmers thus preferred using work vessels of smaller sizes even though the production units grew, and a mismatch between the required work vessel/equipment size and production units prevailed. Insufficient power and size of work vessels have been described in [23]. Few mandatory safety requirements for the design of the work vessels were established, as these types of vessels fell in between different areas of regulations by the Norwegian Labor Inspectorate Authority (LIA) and the Norwegian Maritime Authority (NMA). Hence, in 2012 the NMA started to develop new regulations regarding stability, the use of cranes and fire safety for all cargo vessels, including work vessels for fish farming. In 2015, the new regulation came into force [40]. This regulation applies to all work vessels longer than 8 meters and less than 24 meters from January 1st, 2017, and addresses challenges and specific needs in fish farming [41]. The new regulation may lead to the use of larger and safer vessels in the aquaculture industry in the future.

The NYTEK regulation [42] was first implemented in 2004 and updated in 2012. This regulation requires that the technical standard NS9415 (Marine fish farms – Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation) is used for approval of technical components in fish farms. The main objective of the regulation is to prevent the escape of fish through an improved technical standard of the fish farms [19]. More thorough requirements regarding the design of the fish farms and the planning of operations and maintenance have been implemented. The standard appears to have contributed largely to a reduction in escape incidents due to fewer structural failures [16]. The regulation is not directly aimed at safety for the personnel working on the fish farms, but improved structural robustness of production units and equipment used at fish farms can contribute to a reduction of occupational hazards.

4.3.3 Company size

The fish farming industry in Norway has evolved from a peripheral industry consisting mainly of small family-owned businesses to fewer larger centralized organizations administering several fish farm facilities. The smaller organizations, which previously dominated the industry, had less need for comprehensive safety management systems, as the communication between the employees was easier and more transparent [23]. Work methods were also less complex and demanding with regard to the number of people involved in operations, the size of equipment and the knowledge required to perform operations. Larger organizations, which are now more common in the Norwegian fish farming industry, require a more formal system for securing adequate feedback mechanisms and measures to be taken concerning safety [35]. However, a larger organization may also imply that more resources are available for working systematically with safety [23].

The development from many small to fewer larger organizations has continued over the last ten years. Allred et al. [43] found that in a representative selection there were 148 businesses operating only one fish farm facility, 232 medium-sized business operating 2 to 15 facilities and only 15 businesses operating 16 to 83. Hence, ten years ago, there were still many small and medium-sized businesses. Today, the five largest companies in the fish farming industry employ 84% of the total workforce. The development has continued in the direction of fewer larger organizations and this has most likely influenced the conditions under which the employees in the industry work. [43] found that this view is supported by the fish farmers themselves, and [44, 45] state that it is more difficult for small enterprises to manage occupational safety. Hence, the decreasing fatality trend may be influenced by the major part of the workforce now being employed by large businesses that should be better equipped to handle challenges related to occupational safety.

4.4 Incorporation of results into safety management

Analysis of injuries and fatalities is an important part of safety management, both on a national level and on a corporate level, and an annual report on occupational accidents and diseases is in itself an important outcome of an accident database [30]. Adequate feedback from the responsible authorities about reported occupational injuries and fatalities in the aquaculture industry is still lacking [10], and should be presented to the industry, so learning can be put into actions for ensuring safety. There are several opportunities to use the statistical data related to corporate safety management – among others for selecting efficient accident preventive measures, as a basis for the development of safety indicators, and as input into risk assessment and modeling.

5.0 Conclusions

This article presents an overview of fatalities in the Norwegian aquaculture industry (1994-2015) with a main focus on the production of Atlantic salmon and trout, which is the dominant type of fish farming in Norway. The data set on fatalities has been collected by SINTEF Ocean. The data provide a composite image of the main challenges regarding occupational safety in the aquaculture industry.

The data set includes 34 fatalities over 36 years, and shows a decrease in the fatality rate in the last 15 years. This is a positive development, nevertheless, it is important that the industry has adequate knowledge of the mechanisms that compromise safety for the employees to achieve sufficient risk reduction. The reduction of the fatality rate can be seen in relation to the implementation of certification and management standards and the introduction of new safety related regulations. The restructuring of the industry into fewer larger companies might have enabled the companies to allocate more resources into HSE. In addition, larger companies are more visible to the public and thus will have stronger incentives to work in a safe and sustainable manner.

The most common modes of fatalities are loss of vessel, man overboard and blow from an object. There has been a change in the incidents leading to fatalities in the last 30 years: whereas loss of vessel during transport was the largest cause of fatalities in the 80s and 90s, work operations, often assisted by cranes, have become the largest cause of the fatalities in the last two decades. Both blow from an object/crushing and man overboard fatalities occurred during these operations. Fish farm work vessels and the equipment installed on these vessels are thus still involved in many of the fatalities.

There has been a development in the types of vessels used in fish farming during the last three decades; however, the results presented here should evoke further investigations into how and why work operations influence occupational safety, and actions aimed at increasing safety during these operations are necessary.

The presentation of incidents by month shows that the number of fatalities increases in the autumn and winter months when the weather is harsher than during the rest of the year. This also coincides with the escape statistics, because more escape events occur in these same months. The relation between personal injuries and preventing fish escape events should be further researched, including possible conflicts of interest for safety consequences.

The results should also be seen in relation to organizational safety in aquaculture. Official investigations into fatal accidents show that organizational factors, such as inadequate risk assessment of operations and insufficient training, have been contributing factors to the fatalities. Authorities and companies should employ thorough and systematic use of the data in order to prevent incidents, injuries and fatalities.

Injuries in aquaculture are specifically addressed in a separate related article [10].

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