Marine Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

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

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ARTICLE INFO

Keywords:
Aquaculture
Risk
Occupational safety
Occupational fatalities

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 to 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.

1. 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% 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 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

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http://dx.doi.org/10.1016/j.marpol.2017.08.005
Received 20 June 2016; Received in revised form 24 July 2017; Accepted 4 August 2017

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. Also, 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 [10] 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. 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 h [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 Fig. 1.

3. 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).

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

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	N/A
Fatalities	3	2	0	0	1	0	1	0	1	0	0	1	0	3	1	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	2,12	0	N/A