Occupational safety in aquaculture – Part 1: Injuries in Norway

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Abstract

This article presents an overview of reported injuries in the Norwegian aquaculture industry focusing on the production of Atlantic salmon and trout, which dominates the fish farming industry in Norway. Two different data sets form the basis for the analysis: (i) occupational injuries reported to the Norwegian Labor and Welfare Administration, and (ii) *serious* occupational injuries reported to the Norwegian Labor Inspection Authority. The data sets on occupational injuries and serious injuries provide information about mode of injury, type of injury, affected body parts, and time of year of the reported injuries. The results and the injury trends are analyzed and discussed in light of important characteristics and changes in the Norwegian fish farming industry, including underreporting. This information is useful in safety management and for allocating resources for risk-reducing measures.

Keywords

Aquaculture, risk, occupational safety, personal injuries

1.0 Introduction

The aquaculture industry is well established in Norway, and further expansion is possible provided production and environmental challenges are met. In 2010, 1 million tons of fish was farmed in Norway, this number could be increased to 5 million tons by 2050. [1]. The industry is an important employer in Norwegian coastal districts and the workforce demand spans wider than the actual fish farms, as the industry also requires providers of equipment and services. This makes the aquaculture industry one of the most important socioeconomic factors for sustaining the rural communities in Norway [2].

The complete production line of farmed salmon and trout includes juvenile production, grow-out production and processing. Juvenile production, or land-based production, takes place on land, indoors or outdoors, where the fish, after hatching, are held in fresh water in smolt tubs with a diameter of 2 to 16 meters and a height of up to 4 meters (see Fig. 1). The workers access the largest tubs by ladders to elevated platforms, meters above the ground. Farming of juvenile salmon and trout requires fresh water and the facilities are often located where fresh water can be taken from lakes and rivers. The fish need to be moved to seawater when they are mature enough, usually after one year. This is mainly done by transferring the fish to well vessels, which sail the fish to the sea-based

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fish farms located in or outside the fjords. After about one and a half years, the fish are again transferred to well vessels, which deliver the fish for processing on shore.

The general mode of production for sea-based fish farming in Norway is net cages, either suspended from floaters, such as steel platforms, or from individual circular plastic collars with installed gangways (see Fig. 1). Net cages on steel platforms vary in size from 20 to 40 m in length and a depth of 20 to 35 m, whereas the circular plastic collar net cages are 90 to 157 m in circumference and 15 to 48 m deep. Steel platforms usually contain between four and 28 rectangular or square net cages per site where the cages are placed on a common platform. Sites with circular plastic collars usually have six to 12 net cages per site and are moored individually to an anchoring grid, and vessels have to be used to transport the fish from one net cage to another [3]. Circular plastic collars are installed with a greater distance between the production units and thus provide a better water quality and oxygen supply for the fish. There is a general shift from using steel platforms to circular plastic collar net cages because of their structural properties in harsh weather and the feasibility of maneuvering around the cage during operations.

Some basic operations can be performed manually from the platforms from which the net cages are suspended. These basic operations include daily inspection rounds to check the floaters, the nets and other equipment for damage. Most of the substantial operations, however, require stronger equipment and machinery, such as cranes and winches. These operations are performed from work vessels, which are moored to the net cages. This constitutes an unstable work platform since both net cages and vessels move with wind, waves and sea current. Operations carried out in this manner include net handling, removal of dead fish, fetching fish from the cage for lice counting and other operations related to maintenance such as tightening underwater moorings. Operators in the fish farming industry have expressed concerns for lifting operations involving the use of cranes and winches with regards to personal safety [4]. These operations have also been identified as critical in terms of potential escape of salmon from the fish farms, due to resemblance in the contributing factors leading to both injuries and escapes [5].

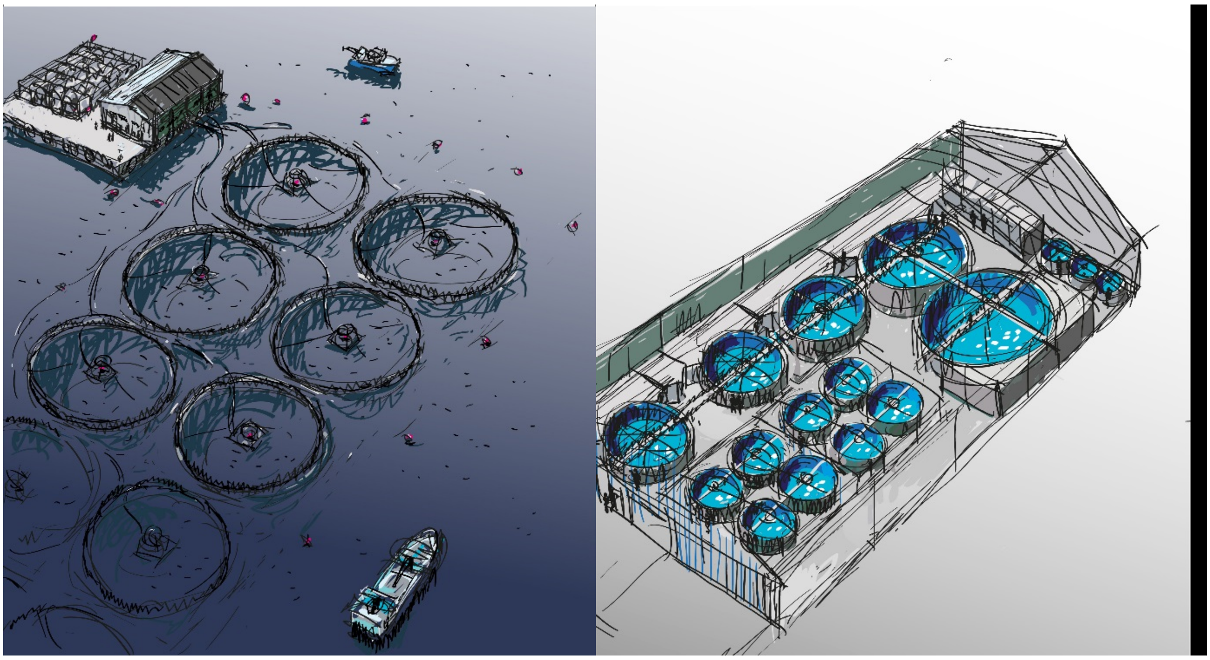

Fig. 1. Sketch of a sea-based production site (left) and a land-based production site (right)

Limited research efforts have been made towards improving occupational safety in the Norwegian aquaculture industry, and no in-depth analysis of injury statistics is available. Given the worldwide size of the workforce in aquaculture and its rapidly growing production [6], there is very sparse internationally published research on the occupational hazards that the workers face on a daily basis [7]. A large part of the research on occupational safety in aquaculture originates from medical research [7-9], and mostly comprises descriptive presentations of the hazards aquaculture operators face [7, 10-12]. Examples of hazards presented in the literature are provided by Myers and Durborow [6], where noise, cuts, sprains, asthma, chemical burns, hearing loss, slips and falls, infections and hypothermia are amongst the common challenges. In addition, the work operations in different types and modes of aquaculture production vary greatly; thus, the hazards vary accordingly. Myers [8] presents consequences related to different species produced, which also shows that even though some consequences are present in several production types, each type of production has its own set of characteristic hazards.

Historical data are important to understand the risk phenomena to be studied [13]. Knowledge about data regarding occupational incidents and fatalities in an industry is valuable input to risk analysis, which is a common method used in managing safety in organizations [6, 14-16]. A statistical overview of, for example, types of injuries, injury mode, fatalities and operations conducted at the time of the occurrence of fatalities will support risk assessments. A common source of statistical data regarding occupational injuries is mandatory accident reporting. However, underreporting is a challenge in many official accident-reporting systems [17-19]. A study of the Norwegian official reporting system for occupational injuries from all industries was conducted in Oslo in 2001 [19]. The study showed a high level of underreporting in all professions. Underreporting might thus influence the results found using official reporting systems. However, the information found through statistical data is an important step towards understanding the characteristics of accidents that occur in a particular industry. General underreporting is thus not an argument for not investigating existing statistical data about injuries. Through employing the data in analysis, improvements of the current reporting system can also be suggested, e.g. by proposing information that should be added to reporting.

The overall objective of this article is to provide a quantified overview of occupational injuries in the aquaculture industry in Norway through analysis of the available information in the two different official registries of occupational injuries. More specifically, the article focuses on the following study objectives: (i) to investigate whether the number of injuries in Norwegian aquaculture shows an increasing or decreasing trend; (ii) to determine injury characteristics and rates of the injuries in the two registries, e.g. types of injuries, injury modes and body areas affected; and (iii) to assess whether there are distinctive injury characteristics to the land-based production mode of fish farming. The extent of underreporting related to occupational injuries is also discussed. The above information enables targeted risk reduction efforts in planning of operations, for risk assessments in the companies, and for mitigating hazardous events in both the private and public sector. The article is related to [18], which focuses on occupational fatalities in the Norwegian aquaculture industry.

The following parts of this article is structured 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 occupational injuries from the aquaculture industry in this article are collected from two different sources: (i) the Norwegian Labor and Welfare Administration (NAV), and (ii) the Norwegian Labor Inspectorate Authority (LIA). The two data sets contain data from the official systems for reporting occupational injuries of which the LIA until recently has been the end receiver. There are two official reporting systems due to different regulations, which means that the data sets represent different types of reported injuries. Ideally, all reported injuries reported to LIA should also have been included in the data set from NAV. This is, however, not the case, and therefore we have to use both data sets in the analysis in the article. Also, the two data sets on occupational injuries are from two different time periods and are therefore presented separately. Only the periods presented were made available upon request to LIA, due to limitations in the reporting system.

In the data sets, each entry represents one person injured. If more than one person has been injured in relation to the same incident, there is one entry for each injured person.

2.1 Data reported to the Norwegian Labor and Welfare Administration (NAV)

The NAV system of reporting occupational injuries is founded on regulations stating that to get access to an additional national insurance service after an occupational injury, the injury needs to be reported. The employer is required to fill in and send the injury report, however if this is not done the injured can also send the injury report. If the injury qualifies as an occupational injury, the injured person will be compensated according to factors such as age, family situation and seriousness of injury. This register includes all levels of injuries, and 761 injuries from the years 2001–2012 have been analyzed in this article [21]. These injuries are reported to the NAV, and then forwarded to the LIA, which until 2013 was responsible for collecting data on occupational injuries.

2.2 Data reported to the Norwegian Labor and Inspection Authority (LIA)

This registry only includes *serious* occupational injuries. Serious injuries are defined as head injuries/concussions, bone injuries, internal injuries, loss of limb, poisoning, loss of consciousness, thermal injuries, hypothermia and any injury that requires treatment in hospital [22]. There is a legal obligation on the employer to report serious occupational injuries directly to the LIA. Seventy-nine injuries of this type were registered in the period 2011–2013 and are analyzed in this article [23].

2.3 Normalization of data

To normalize the data for comparison purposes injury rates have been calculated. All injury rates are based on the number of person-years in the aquaculture industry (see Table 1). Person-years are calculated by dividing the number of workers by the hours worked per year, defined as 1750 hours [24, 25]. In general, the number of person-years has increased steadily over the last 20 years, and was 4378 in 2012.

2.4 Limitations in the data material

Studies of official reporting systems suggest that there is a high level of underreporting of occupational injuries. Artisans and operators, who constitute a large proportion of the employees in the aquaculture industry also have higher levels of underreporting than the average [17, 19]. A cross-check of the two data sets on occupational injuries shows that there is little overlap (eight out of 49 injuries are present in both data sets for the years 2011–2012). More overlap could have been expected since this would have secured access to reimbursement of health-care expenses due to an occupational injury, and also for compensation in case of long-term injury. Thus, the rates found in the data set of occupational injuries reported to the NAV must be considered as a minimum of actual rates, since injuries might be missing. Underreporting of injuries to the authorities is further discussed in Section 4.3.

3.0 Results

This section presents the results from two separate analyses of data on occupational injuries from the NAV and the LIA (see Section 2). The injuries found in both the NAV and LIA registries are only included in the analysis of injuries reported to the LIA (Section 3.2). The injury rates for the two main production modes, juvenile production (land-based) and grow-out production (sea-based), are presented together, but a comparison between the separate injury rates for the two production modes has been included where relevant. All figures in the article represent the combined results for the two production modes.

3.1 Occupational injuries reported to the Norwegian Labor and Welfare Administration (NAV) 2001–2012

The data reported to the NAV cover 761 occupational injuries from 2001 to 2012, which is included in Fig. 3. A total of 609 injuries were reported from sea-based production and 152 injuries from land-based production. All occupational injuries are required to be reported to the NAV, regardless of how serious the injuries are. The results in the following subsections are presented in terms of number of yearly reported occupational injuries, mode of injury, injury type and affected body areas, age and gender, time of year of reported injuries and location in Norway.

3.1.1 Annual overview of occupational injuries and trends

In general, there has been a decline in the number of injuries reported since 2001. The number of person-years has been steadily increasing since 2004, with a decrease in the reported injuries; the total injury rate is therefore also decreasing (see Table 1). The highest injury rate for the aquaculture industry occurred in 2004, with a rate of 280.9 injuries per 10,000 person-years, while the lowest rate occurred in 2011, with 82.3 injuries per 10,000 person-years. Norwegian fisheries is considered one of the most dangerous professions in Norway [26, 27]. The highest total injury rate (including fatalities) for fisheries in Norway in the period 2000-2013 occurred in 2000, when the injury rate was 229 per 10,000 person-years. The corresponding injury and fatality rate for the period available for aquaculture (2001-2012) is 191.7 injuries per 10,000 person years. A decline in injury rate is also shown in fisheries, and in 2013 the injury rate was 93 per 10,000 person years [28]. The yearly injury rate of Norwegian aquaculture is thus comparable to that of other professions considered to present high risk to workers.

Table 1. Person-years, number of injuries and injury rates per 10,000 person-years, 2001–2012 [21, 24]

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Person-years	3070	3205	3139	2919	2953	3203	3367	3659	3764	4063	4251	4378
Injuries	78	81	63	82	79	61	70	73	53	46	35	40
Injury rate per 10,000 person-years	254.1	252.8	200.7	280.9	267.5	190.5	207.9	199.5	140.8	113.2	82.3	91.4

3.1.2 Mode of injuries and injury types

Fig. 2 shows the mode of injury over the period 2001-2012. The four most common modes of injury are *fall*, *blow from an object*, *entanglement or crush* and *prick/cut/puncture*. The injury rate of falls is 49.3 per 10,000 person-years, while blow from an object which is the second most common mode of injury with 37.2 injuries per 10,000 person-years.

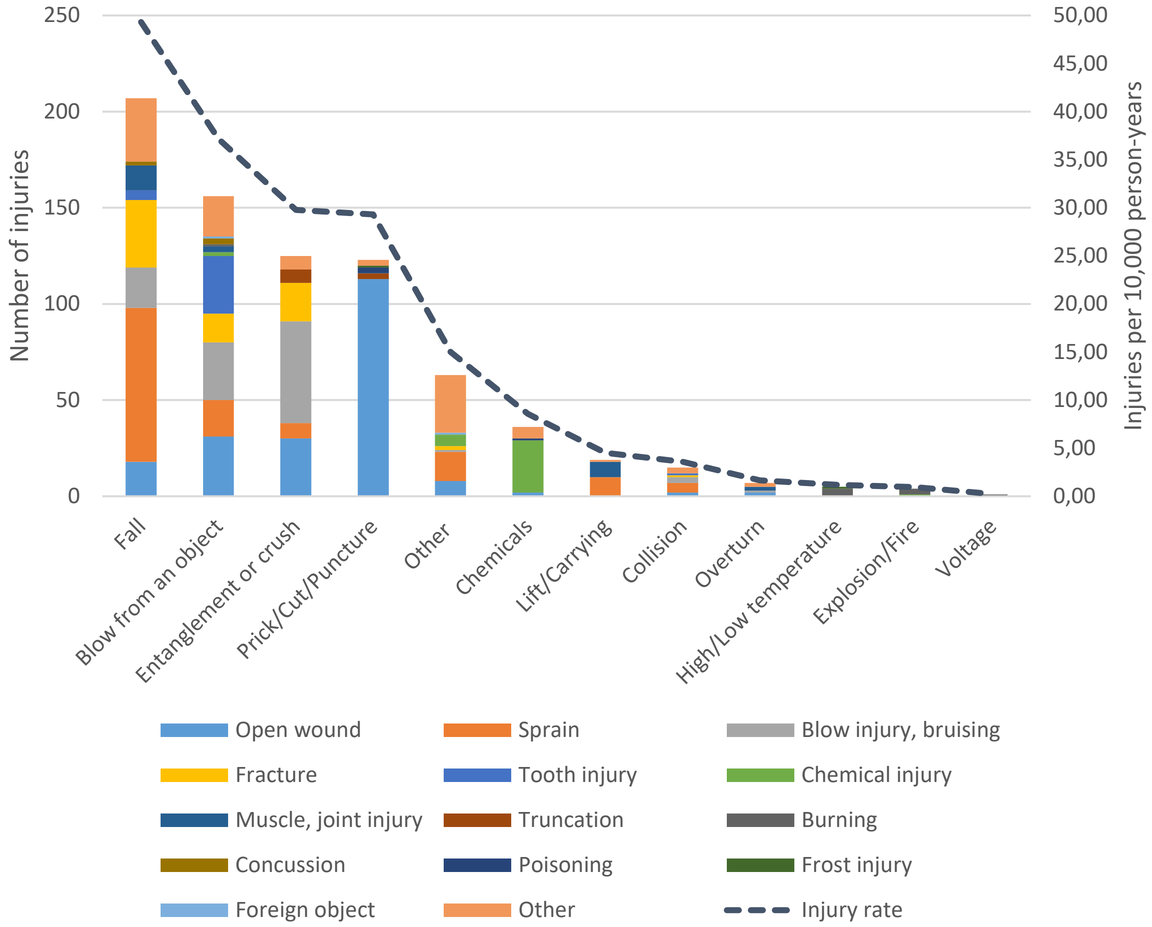

Fig. 2. Mode of injury and injury types in Norwegian aquaculture 2001–2012. Injury rate per 10,000 person-years is based on total number of person-years in the same period [21].

The mode of injury *fall* can be divided into two groups: (i) falls to the same level, and (ii) falls to a lower level. Falls to the same level include slipping from a wet/icy surface, often on the deck of a vessel or on a net cage. The category *falls to lower level* includes injuries occurring due to movement between vessel and quay, vessel and net-cage, vessel and feeder barge, or vessel and vessel. The mode *blow from an object* most often happens in relation to slips with handheld tools. Other situations that contribute to this mode of injury are hits from an operated crane, recoil of hawsers released from tension, and hit by trapdoors caught by wind. These modes of injuries mostly happen in relation to operations on the deck of work vessels or on the net-cage. *Entanglement/crush* is mostly caused during lifting operations, using cranes and capstans, when limbs easily get caught between, e.g., ropes and capstan or between objects held by crane and net-cage.

Prick/cut/puncture injuries mostly happen when a knife slips while gutting fish, carrying out repairs or cutting ropes. Other tools that cause cuts are an angle grinder and a knife shaped as a cross, which is used for opening fodder sacks while they are suspended by a crane.

In Fig. 2, the injury mode and the resulting injury types can be found. The most common injury types are *open wound*, *sprain*, *blow or bruising injury* and *fracture*. *Open wound* injuries have the highest rate of 49.1 per 10,000 person-years. More than half of the open wound injuries are the result of a *prick, cut* or *puncture*. *Sprain* is the second most common injury type with a rate of 32.6 per 10,000 person-years. Sprain injuries occur in more than half of the cases caused by *falls*. *Blow injury* or *bruising* happens at a rate of 26.0 injuries per 10,000 person-years and is mostly caused by *entanglement* or *crush*. The fourth most common injury type, *fracture* (injury rate 14.3), is largely caused by *falls*.

3.1.3 Injured body areas

Fig. 3 shows that *fingers* are the most exposed body area with an injury rate of 36.5 per 10,000 person-years. *Hand/wrist*, which is the second most exposed body area, has an injury rate of 22.4. *Fingers* and *hand/wrist* most commonly suffer from the *open wounds* injury type due to the injury mode *prick, cut* or *puncture.* However, *entanglement or crush* causes almost as many injuries to the fingers and hands like *open wound*, *sprain* and *bruising*.

The next two most commonly injured body areas are the *ankle/foot* and *arm/shoulder*, and in most cases they are affected by *sprain* injuries.

Head and *eye* injuries, which are injuries with long-term consequences, have injury rates of 12.9 and 12.6, respectively. *Falls* and *blows* from an object cause head injuries. *Eye* injuries are in most cases caused by incidents involving chemicals.

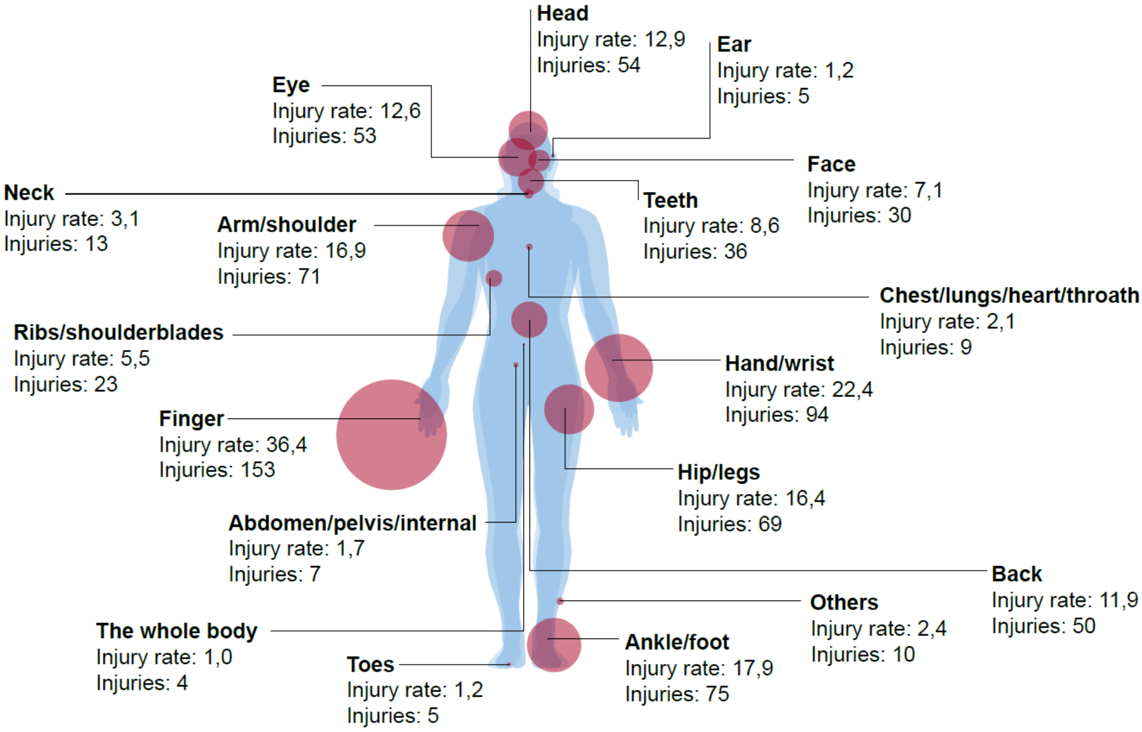

Fig. 3. Body parts injured in occupational accidents in Norwegian aquaculture 2001–2012 [21]. Injury rate per 10,000 person-years is based on the total number of person-years in the same period.

3.1.4 Age and gender

Table 2 shows the number of injuries per age group. The two age groups 25–34 and 35–44 have the highest number of incidents. Around 85% of the injured are men. In 2001, 91.7% of the employees in the aquaculture industry were male. In 2012, this number was 90.6% [24]. It has not been possible to obtain person-years per age group; hence injury rates per age group are not presented.

Table 2. Number of injuries per age group in Norwegian aquaculture 2001–2012 [21].

Age group	Number of injuries
15-19	36
20-24	97
25-39	303
40-54	227
55-67	93
Over 67	6

3.1.5 Injuries per month

Autumn and winter months have the highest number of injuries (see Fig. 4). These months have harsher weather conditions that may influence the work, especially for the sea-based production activities.

Over the year, a higher share of the youngest age group is injured in the summer months of July and August. It is normal practice in the aquaculture industry to hire young people, such as students, for summer jobs in these months. Hence, there is a higher share of young and inexperienced employees during the summer months than in the rest of the year, but sufficient information about person-years is not available to calculate injury rates (see Section 2.4).

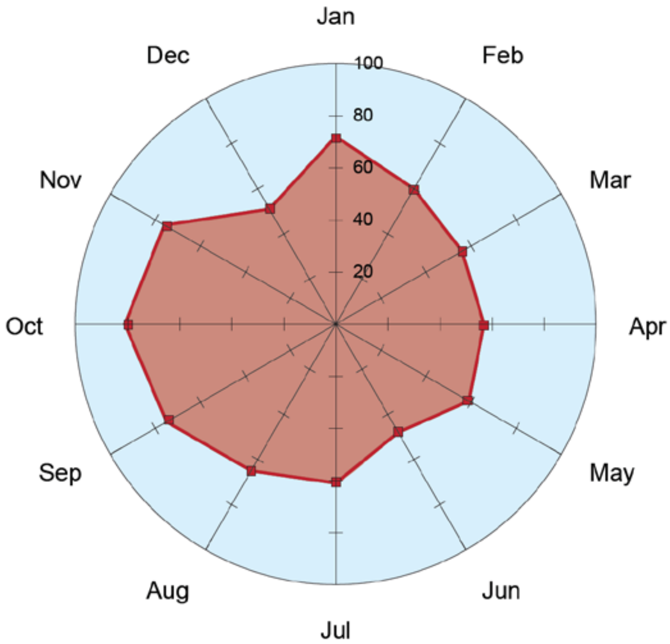

Fig. 4. Number of injuries per month in Norwegian aquaculture 2001–2012 [21].

3.1.6 Distinctive injury characteristics in land-based production

152 of the injuries presented here were reported from land-based production. As the production mode in land-based aquaculture is different from sea-based production, some distinctive characteristics for land-based production should also be presented.

In land-based production *fall* is the most common injury mode. The falls happened mainly due to slippery surfaces and falls from heights. The second most common injury mode is *blow by object,* where a range of different object were involved, e.g., pallets, batteries and pipes. The most common injury type is *sprain,* which are mostly associated with falls. *Open wound* injury is the second most common injury type in land-based production. Open wound injuries are mostly often caused by *prick, cut or puncture*, which is the third most common injury mode. *Fingers* are most exposed in land-based production, and *ankle/foot* are the second most injured body parts, while *hand/wrist* are the third most injured body parts.

3.2 Serious occupational injuries reported to the Norwegian Labor Inspection Authorities (LIA) 2011–2013

The data from the LIA are based on mandatory reporting of serious occupational injuries in the aquaculture industry from 2011 to 2014 (for a definition of "serious injuries," see Section 2.2). A total of 92 injuries were reported from sea-based production and 17 injuries occurred in land-based production. All serious injuries are required to be reported directly to the LIA by the employer, however, many injuries are also reported by authorities notified about the accidents, such as health care and police. The results are presented in terms of total numbers of injuries reported per year, mode of injury, injury type and affected body areas, age and by month.

3.2.1 Annual overview of serious occupational injuries and trends

From 2011 to 2014, in total 109 accidents were reported to the LIA (see Fig. 5). The injury rate was just over 60 injuries per 10,000 person-years over the four-year period, expect for the year 2012 when there was a decline in reported injuries, which led to an injury rate of 52.4 injuries per 10,000 person-years.

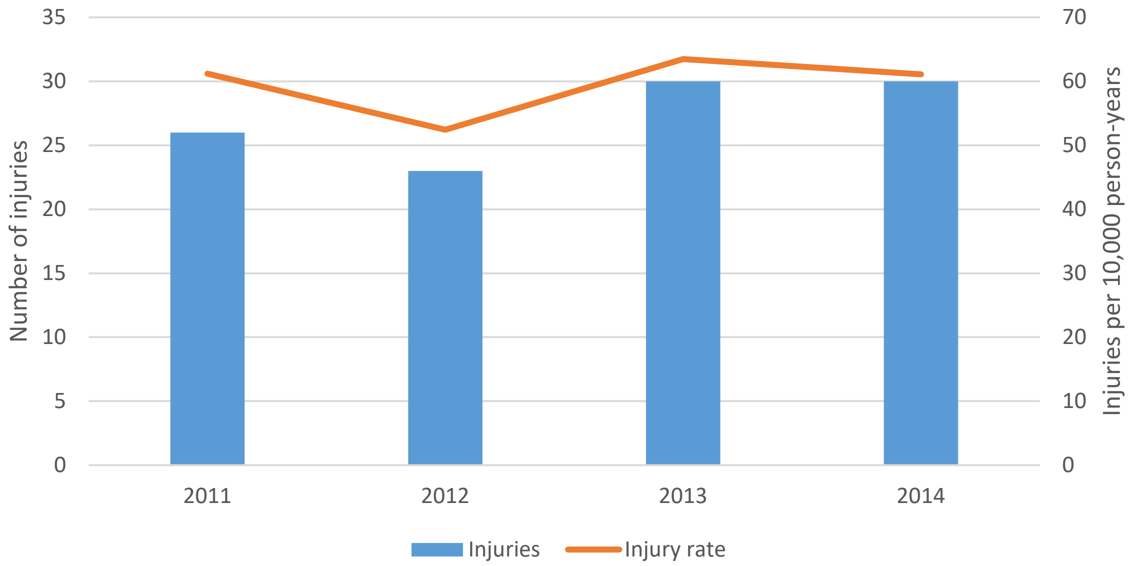

Fig. 5. Number of injuries and injury rate of serious injuries 2011–2014 [23].

3.2.2 Mode of injury and injury type

The most common mode for serious injuries is *blow from an object,* as shown in Fig. 6. A total of 25 injuries of this type were reported from 2011 to 2014, which gives a rate of 13.7 injuries per 10,000 person-years. Almost one third of these injuries involve the use of a crane and objects falling from the crane onto workers in the proximity of the crane. Other examples of *blow from an object* injuries involve the recoil from wires and ropes accidentally released from tension, and heavy trapdoors hitting workers when caught by wind.

The second and third most frequent mode of injury are *entanglement or crush* and *fall,* which are both reported with rates of 10.4 injuries per 10,000 person-years. Examples of *entanglement or crush* injuries are limbs crushing between ropes and capstans, or otherwise getting caught in ropes or chains during lifting operations by use of a crane. Most of the *fall* injuries are due to falls to a lower level, the most common situation being falls from a ladder.

Voltage injuries, with a rate of 8.2 injuries per 10,000 person-years, are caused by static electricity from plastic fodder tubes used in sea-based production. Electricity is released when, for example, the tubes are sawn through or flushed with hoses.

The data registered by the LIA are is insufficient with regards to the injury types resulting from accidents. Less than half of the injuries in the available data entries include information on injury type, thus it is not suitable to present these data. Of the registered injury types, *fracture* is the most common and is, in almost half of the cases, caused by a blow from an object.

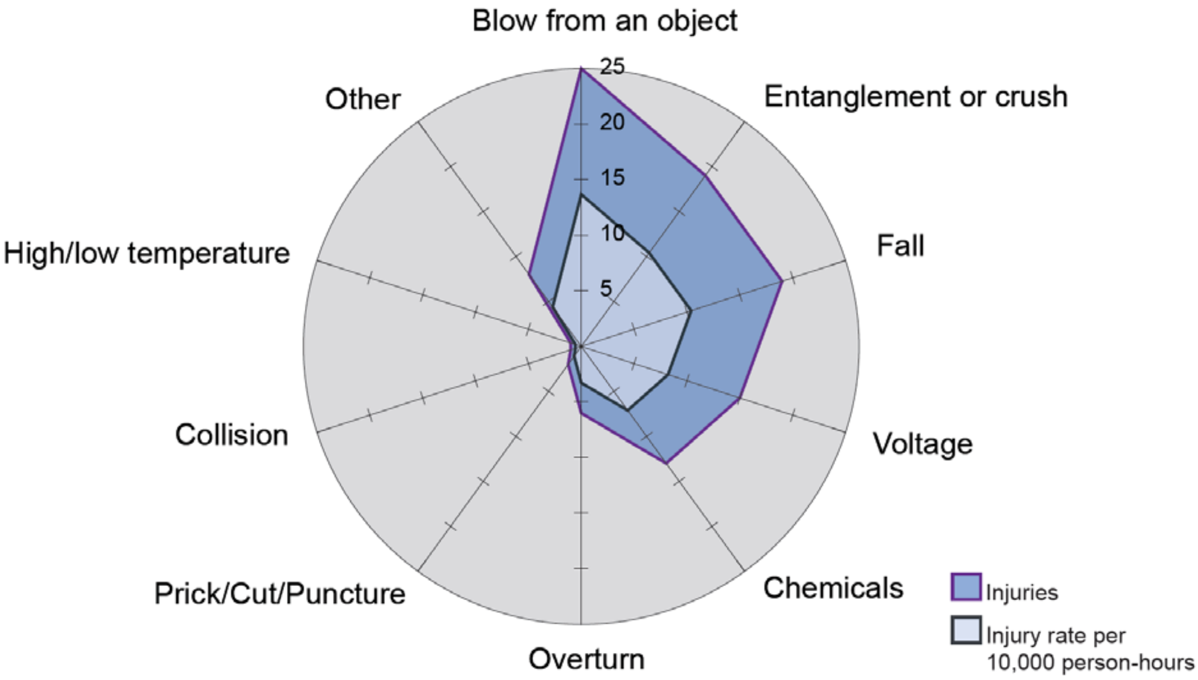

Fig. 6. Mode of injury of serious occupational injuries in Norwegian aquaculture 2011–2014 [23]. Injury rate per 10,000 person-years is based on the total number of person-years in the same period.

3.2.3 Body areas affected

85 of the 109 registered accidents contain information about the body area affected (see Fig. 7). The mode of injury *voltage* causes a correspondingly high number of injuries affecting the whole body. This is also the highest number of injuries in one category, with 15 injuries affecting the whole body (8.2 injuries per 10,000 person-years). In 14 of these cases, static electricity in fodder hoses led to the injury. This type of electric shock has fewer consequences than electric shock caused by electric current, but it is very painful and can lead to burn injuries and short-term paralysis. The second most affected body area is the head, with 13 injuries and 7.1 injuries per 10,000 person-years. It is not possible to determine the exact types of head injury due to a lack of information in the data set from the LIA. However, the injury modes causing most of the *head* injuries are *blow from an object* and *falls*. The *hand* and *foot* are the third and fourth most injured body parts, respectively. Most of these injuries are *fractures* or *open wounds*, and the injury types vary from *blow from an object* and *entanglement or crush* to *fall* and *prick or cut* by sharp object. Drowning incidents are the fourth most common group in the statistics over the body areas affected. Six of these incidents are injuries to divers, during or after diving (bends), and three are in relation to capsizing.

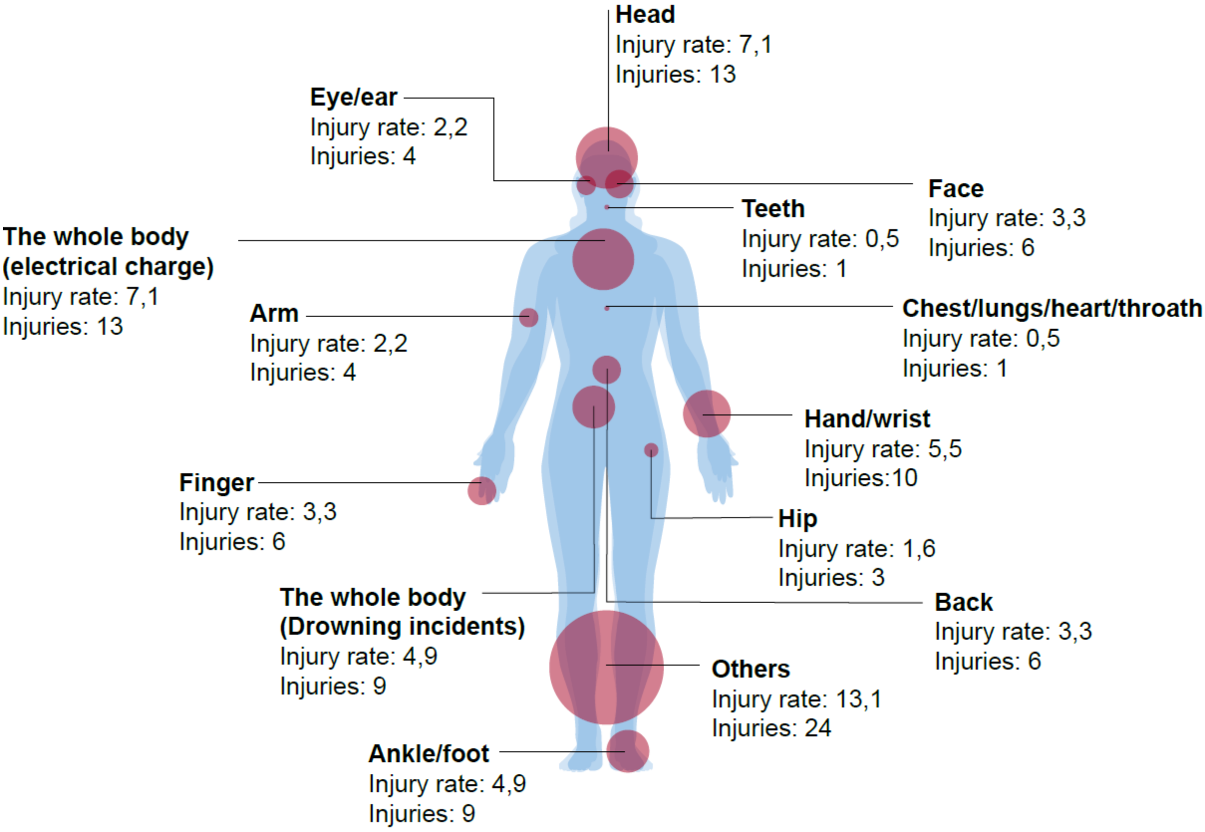

Fig. 7. Body areas affected by serious occupational injuries in Norwegian aquaculture 2011–2014 [23]. Injury rate per 10,000 person-years is based on the total number of person-years in the same period.

3.2.4 Age

The age distribution of the injuries shows that most of the serious injuries occur in the 25–39 age group (see Table 3). There is no information about age from 2014, which leads to a very high number of incidents where the injuries have an unspecified age. It has not been possible to obtain person-years per age group; hence injury rates per age group are not presented.

Table. 3. Number of serious occupational injuries per age group in Norwegian aquaculture 2011–2014 [23].

Age group	Number of injuries
15-19	6
20-24	8
25-39	23
40-54	17
55-67	6
Over 67	1
Unknown	48

3.2.5 Incidents by month

Fig. 8 shows the number of serious injuries over the year. October is the month with the highest number of recorded injuries: 14 injuries were reported this month, two more accidents than in August, which had the second highest number of injuries. Two of the injuries in August occurred to workers in the 15–19 age group, who were hired as seasonal workers. In five of the injuries reported, weather was explicitly mentioned as a factor contributing to the injury. These injuries happened in the months October–March.

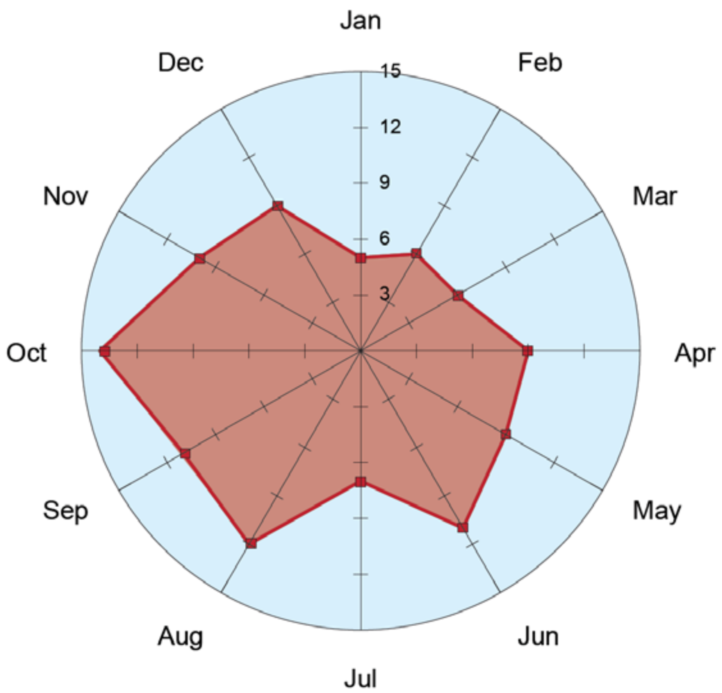

Fig. 8. Number of serious occupational injuries per month in Norwegian aquaculture 2011–2014 [23].

3.2.6. Distinctive injury characteristics in land-based production

For land-based production, in total 17 injuries were reported. The injury mode *fall* is the highest contributor to serious injuries in land-based production with eight injuries. The falls happened mostly from ladders, both when accessing the smolt tubs, and other maintenance work. These fall injuries led to fractures, sprains and bruising to the hands, hips, head and, back. Additional remarks for land based production cannot be made, due to lack of information for the reported injuries.

4.0 Discussion

4.1 Trends and characteristics of occupational injuries in Norwegian aquaculture

The injury rates of the occupational injuries reported to the NAV show a steady decline in the years 2001–2012, from 254 to 91 injuries per 10,000 person-years. The injury rate of the serious occupational injuries reported to the LIA remained mainly stable at just above 60 injuries per 10,000 person-years over the period 2011–2014. Influencing factors related to the decline in reported injuries are discussed in Subsection 4.2 and in [20]. There are only two overlapping years between the two registries presented in this article, 2011 and 2012, in these years the injury rates are higher in the data from the NAV. It is to be expected that a higher number of injuries are reported to the NAV than serious injuries to the LIA.

Table 4. The four most common modes of injury and injury rates in the LIA registry for the period 2011-2014 and the NAV registry for the period 2001-2012.

LIA registered injuries 2011-2014	Injury rate per 10,000 person-years	NAV registered injuries 2001-2012	Injury rate per 10,000 person-years
1) Blow from an object	13.7	1) Fall	49.3
2) Entanglement	10.4	2) Blow from an object	37.2
3) Fall	10.4	3) Entanglement	29.8
4) Voltage	8.2	4) Prick/Cut/Puncture	29.3

Table 4. shows the four most common mode of injury and injury rates in the two registries. The injury rates are generally higher in the registry from the NAV. The three first modes of injury are the same in the two registries. However, the causes for the injury modes differ to some extent in the two data sets. In the data set from the NAV, most *blow from an object* includes slipping with handheld tools. The serious *blow from an object* injuries in the LIA registry happen when objects held with a crane are dropped and fall on workers in the proximity of the operation or when a crane is used for suspending and hawsers tear or slip. Trapdoors getting caught by wind is also a contributor to these accidents in both registries. *Blow from an object* injuries reported to LIA cause injury mostly to the head, foot/ankle and back. The same body areas affected are seen in the NAV registry, in addition to teeth being affected.

Loss of control when using a crane is also a contributing cause in the e*ntanglement* injuries reported to the LIA, as workers are crushed between the net cage and other lifted objects. Similar causes are found in the entanglement injuries reported to NAV, in addition to injuries due to limbs getting caught between capstan and ropes. The largest group of injury type due to entanglement in the NAV registry is *blow injury or bruising,* while in the LIA registry the consequences (when reported) are *fractures* and *open wound*, which could be characterized as more serious consequences. The crane and capstan are equipment on the working vessels used for lifting, which is an important part of many operations both in relation to tending the fish and maintenance of the net-cages. Operators are in many of the operations required to be in close proximity of the crane, e.g., for working on equipment lifted by the crane and in these situations injuries may occur. Capstans are handled manually and the rotation of the equipment is a contributor to injuries. These operations are also considered to be critical in relation to escape events, which is a major focus in the fish farming industry [5].

Fall is the injury mode which is most reported to the NAV, and third most reported to LIA as a serious injury. *Falls* are in the two registries happening both to the same level and to a lower level. Falls are prone to happen when operators are on the deck of a work vessel, and especially when moving from one work unit to another. As workers are required to perform daily inspections of the net cage and the fish, working and moving on the vessel and between units are frequent and inevitable. Vessels and net cages are naturally unstable work platforms, and the seawater makes surfaces slippery, which increases the likelihood of fall injuries. *Sprains* and *fractures* are the most common injury types related to fall, and the limbs *foot/ankle* and *arm* in addition to *back* and *hips* are most affected by this injury mode in the NAV registry while, the *head* is the most affected in the reported serious injuries to LIA.

Prick/Cut/Puncture, which is the fourth most common injury mode in the NAV registry, is barely reported in the LIA registry (1.09 injuries per 10,000 person-years). In both registries, it is the *hand/wrist* and *finger* that are most affected. The injuries of this mode is mainly caused by the use of knives in the NAV. In the LIA registry the injuries are related to use of electrical saw and maintenance of a rotary axel, thus the consequences are also more severe.

The injury mode *voltage* is present with a much higher rate in the registry over serious injuries from LIA than from NAV (0.24 injuries per 10,000 person-years). This injury mode is mainly related to static electricity in fodder tubes, which is used only in sea-based production. Also drowning incidents is only present in the LIA registry, and seen in the reported body area affected, *whole body affected (drowning incidents)*. These are injuries with potentially severe consequences, and in particular drowning incidents, which in several cases have led to fatalities, should be handled with caution (see [18]).

Almost half (eight) of the *fall* injuries in the LIA registry, and one-third (52) of the *fall* injuries in the NAV registry, are reported from land-based production. Working at heights and slippery surfaces are the most common causes for this injury mode. The smolt tubs in land-based production can be several meters high, and they are accessed from the outside via ladders and platform gangways at the same height as the tubs. Cleaning and maintenance of the inside of the smolt tubs are performed when they are drained of water, and ladders are often used to gain access. Thus, extra precautions should be taken to improve the safety of these operations.

The injuries in both data sets show an increase during the autumn and winter months. These months have more severe weather conditions in addition to shorter daylight periods, which may explain the seasonal peaks. August is the month with the second highest number of serious injuries. In the vacation period, and as described in [20], less experienced personnel are hired to replace and assist the regular employees. Hence, more inexperienced employees and more complex work operations, such as delousing, which is often performed during the summer, might lead to higher risk for the workers.

4.2 Safety regulations' influence on injury rate

Several factors may influence the decreasing injury rates in the fish farming industry. Increased use of certification and focus on standards, improved technology development and a restructuring of the industry are factors discussed in the related article [20]. In addition, new regulations relevant to safety have entered into force, which may have improved the focus on safety management in the industry.

One of the main regulations is regarding systematic health, environment and safety (HES) work in enterprises – the internal control regulation [34]. The regulation first came into force in 1992 in Norway, and the latest revision was carried out in 2013. All land-based enterprises, including aquaculture, are subject to this regulation. The objective of the internal control regulation is to promote: (i) work environment and safety, (ii) prevention of injuries or environmental disturbance from products or services, and (iii) protection against harm to the environment and improvement of waste treatment. A study of the systematic HES work in fish farming from 2005 [14] found that the industry generally had safety management systems satisfying many of the demands in the internal control regulations, but the implementation of the systems was still not adequate throughout the industry. The internal control regulation ensures that the company's safety management is a continuous improvement process. Hence, this system is expected to improve safety in the long run. In 2009, an interview-based study among personnel in the fish farming industry found that work on safety had improved substantially in recent years [4]. Factors, such as the development of procedures in co-operation with employees, documentation and reporting of safety conditions and training in risk understanding and identification, are all part of the demands in the internal control regulation. The decline in the NAV registered injury rate may therefore to some extent be related to the implementation of safety management systems in companies, in accordance with the internal control regulation. In addition, improved safety management can lead to improved reporting of injuries, which might result in a higher ratio of reported injuries in the last years. This would imply a larger decrease in injuries than what is actually found in the statistics.

4.3 Underreporting and quality of injury reports

Cross-checking the two databases of the NAV and LIA received for the analysis in this article shows a substantial level of missing data in the registry of the NAV. In 2011–2012, 49 injuries were registered in the LIA database of serious injuries. Of these, only eight (16%) were found in the database of the NAV where all occupational injuries should be recorded. High levels of underreporting public injury reporting is also found in other studies [17, 19]. In addition, the majority of the workforce in aquaculture is in the category artisans and operators which have higher levels of underreporting than academic professions and office/customer service professions [19].

4.3.1 Causes for underreporting

Serious occupational injuries are required to be reported directly to the LIA as stated in the Work Environment Act [29]. Nonconformities discovered by the LIA have to be improved and documented in detail, and can require resources the company might not have available. In the most serious cases the LIA can fine the company or report the accidents as a crime to the police. Thus, aquaculture companies could have motives for not reporting the incidents. However, in general, there is a lower level of underreporting of serious injuries and fatalities, as these are more difficult to conceal or overlook [31].

Reporting injuries to the NAV (which in turn should be forwarded to the LIA) is required by the National Insurance Act [30]. The objective of this reporting is for the injured to gain access to (additional) social security payments granted when an injury has happened during work hours. If the incentive for reporting occupational injury according to this requirement only is reimbursement of immediate health-care expenses, the reporting level can be expected to be low. The Norwegian social security system ensures cheap or free health care, all overnight hospitalizations are free, and other health-care treatments are largely covered. If there is suspected long-term illness following the injury, the personal incentives for reporting are higher. Other factors, such as underreporting of injuries internally in companies, can contribute to underreporting by the employers. In addition, inadequate knowledge about the reporting requirements could be a reason for underreporting.

Underreporting between the responsible authorities have also occurred due to an inadequate system for transferring reports from the NAV to the LIA, which up until 2013 was responsible for collecting national statistics on occupational injuries. Statistics Norway have since taken over the responsibility to collect national statistics regarding occupational injuries, and aims to establish a new electronic reporting system between the authorities.

The statutory obligation to report occupational injuries is not enough to ensure adequate reporting; there is also a need for self-motivation among employers and companies to report all injuries [18].

One of the factors that could influence the incentives for reporting is the authorities providing feedback and information to the industry about the injuries that are reported [31]. The public registries of occupational injuries in Norway do not publish sufficient industry-specific statistics about the incidents reported. Providing the industry with well-presented data on occupational injuries would demonstrate how reporting in itself is valuable as it provides a foundation for developing targeted mitigating efforts, and companies are also able to compare safety performance with industry rates.

4.3.2 Quality of injury reports

There are inadequacies in the content of the data provided from the registries employed in this article. For example, the serious occupational injuries reported to LIA lack information about injury type and body area injured. In addition, the data do not provide enough information regarding where on the fish farm the injuries happened, what type of equipment was involved, or during what type of operation the injury occurred. Information about weather conditions and sea states is not sufficiently included in the available data. A reason for the inadequacies in the data might be found in the authorities' incentives for registering the injuries. As mentioned earlier, the incentives for reporting are different in the two registries employed. The NAV data are mainly used to decide whether the injuries can be categorized as an occupational injury. The LIA data are used in the prevention of future accidents, however, the main focus is not on the injury but on the company and whether they have complied with regulations prior to the accident. Thus, information that could be evaluated as important in injury statistics might not be in focus when the injury is registered with the authorities.

5.0 Conclusions

This article provides an overview of occupational injuries in the Norwegian aquaculture industry focusing on injury trends, characteristics and rates, including types of injuries, injury modes and body areas affected, as well as distinctive injury characteristics in the land-based production mode. Two different data sets form the basis for the analyses in the article. The first data set on occupational injuries is collected by the NAV in the period 2001-2012, and the second set on serious injuries is collected by the LIA in the period 2011-2014.

The data sets regarding occupational injuries reported to the NAV show a general decrease in injury rates during the last ten years. This is a positive development.The reduction of the injury rates can be seen in relation to the introduction of safety regulations, such as internal control of HSE systems.

Occupational injuries reported to the NAV and serious injuries reported to the LIA are largely caused by blows from an object, falls and entanglement. Open wounds and sprains are the two most common injury types for occupational injuries. Fracture is the most reported serious injury type, however this information is not complete due to inadequacies in reporting. Cranes and capstans are involved in several of the most common injury modes, and an investigation into the impact of this equipment on the injury statistics would be beneficial for future accident prevention. It is the body extremities that are most often injured in the less serious incidents reported to the NAV, while injuries to the whole body in relation to electric shock and the head are most often involved in serious injuries reported to the LIA. Also, drowning incidents are represented in the statistics, a challenge presented in the paper on fatal occupational accidents in Norwegian aquaculture [20]. Occupational injuries related to land-based production are mainly caused by fall.

Previous research shows that there is general underreporting of occupational injuries to the authorities, and there is also a substantial level of injuries missing in the NAV registry of injuries in aquaculture. Incentives for reporting occupational injuries must be enhanced to improve reporting, e.g., by the authorities presenting industry-specific details about the injuries for learning. These could then be used by the industry to design targeted mitigating efforts, and to compare company statistics internally to nationwide trends.

Fatalities in aquaculture are specifically addressed in a separate related article [20].

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