Organisational safety indicators in aquaculture – a preliminary study

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ABSTRACT: The aquaculture industry has since the 70's grown to become one of the most important industries in Norway. A safety challenge for the Norwegian fish farming companies is escape of salmon. During the last decade, the main cause to escapes has changed from structural failures to "human errors". The paper addresses the need for improving safety in fish farming operations by implementing systematic means for risk management. The objective of this preliminary study has been to evaluate whether the Operational Safety Condition (OSC) method provides a feasible tool for identifying and understanding organisational factors and conditions that influence safety levels at the fish farms. The basis for the study is escape of fish. The results demonstrates that OSC seems to be a promising tool for audits of the organisational safety conditions in aquaculture companies.

1 INTRODUCTION

1.1 *Background*

The aquaculture industry has during the last 40 years grown to become one of the most important industries in Norway, and Norway is now the dominant producer and exporter of Atlantic Salmon worldwide. The industry has been in constant development and is now aiming to reach a production of 5 million tons of farmed fish per year by 2050 (Olafsen et al. 2012), up from around 1.3 million tons in 2013. Due to the increasing need for more space and better production environments (Holmer 2010), there has been a gradual move towards also using more exposed coastal areas. Farming in exposed areas poses unique challenges to operations, structures and equipment, due to extreme weather, wave and current conditions, and sheer remoteness (Bjelland et al. 2015). Technology is gradually developed to meet these challenges; so far mainly by upscaling boats, fish farms and net cages.

Exposed farm locations could be ideal for production and simultaneously reduce key environmental effects, as well as the negative ecological consequences of sea lice (Costello 2009) and escapees (Jensen et al. 2010). Fish farmers, who have gradually started to utilize more exposed locations, report considerable difficulties in maintaining reliable production (Sandberg et al. 2012). Weather conditions are already causing downtime at several sites, especially during the winter months, and this is expected to increase due to climate changes. This makes the overall management of maintenance and daily operation unpredictable, and challenges the safety at the fish farms (Holen et al, 2013). Lack of repairs and daily inspections of fish cages may increase the risk for fish escapes. Maintenance and safety management strategies have to be changed in line with the harsher operating conditions (Utne et al. 2015).

Escape of fish is a great challenge for the Norwegian fish farming companies. A fish escape incident may consist of from one to several tens of thousands of fish being accidently released from a net cage. The fish farmers are decreed to report every escape, also upon suspicion. The number and average size of the escaped fish shall be reported to the Directorate of Fisheries, which will investigate the incident. The company in charge of the escape are obliged to reduce the environmental damage by catching the escaped fish with nets. To avoid new escapees, they must document implementation of relevant actions. The loss of fish implies a financial loss, but perhaps even more damaging is that such accidents severely harm the reputation of the industry. Escaped fish might disrupt gene pools of wild salmon (Bourret et al. 2011), thus affecting the environment. Furthermore, escape of farmed fish is criminalised and the company and/or the employees might be prosecuted and fined if the investigation reveals misactions or noncompliance with mandatory safety procedures. This may lead to severe personal strain (Thorvaldsen et al. 2015). The workers are likely to take action to prevent escapees even though this might expose themselves to hazards (Størkersen 2012).

Current research shows that the accident causality often is complex and with several contributing factors. Such factors are, for example, the harsh work environment that the operators have to deal with, demanding work operations, variations in worker experience and skills, poorly implemented safety management, and suboptimal functionality of technology (Thorvaldsen et al. 2015). Previous interviews with operators and managers at fish farms also show that most of the operations regarded to be critical for the escape of fish, also implies a considerable occupational safety risk. Thus, means for reducing the risk of fish escape may also improve the safety for the workers.

1.2 *Objective and scope of paper*

This paper addresses the need for improving safety in fish farming operations by implementing systematic means for risk management. Risk management deals with identifying, analysing, assessing and controlling occupational risk and major accident risks, as a basis for developing preventive measures (ISO 31000:2009). The management system should enable good safety practice in all parts of the organisation, and ideally, it should have a built-in resilience against human errors. Thus, it is crucial to understand how organisational factors and conditions influence safety levels. Furthermore, internal audits should be performed at intervals in order to check the safety levels in the fish farming companies' daily routines. To make the audits efficient, they need to focus on the critical safety factors relevant for the operations at the fish farms. The objective for this paper is to evaluate whether the Operational Safety Condition (OSC) method provides a feasible tool for identifying and understanding organisational factors and conditions that influence safety levels at the fish farms. The basis for the study is escape of fish.

2 REGULATIONS ON SAFETY MANAGEMENT IN AQUACULTURE INDUSTRY

All Norwegian enterprises are obliged to implement some kind of performance management systems, to control quality, working health, safety and/or possible damage to the environment. These could be integrated in one management system, but typically current practice is that maintenance schedules and records are often found in different systems. Software-based management systems are implemented because it is a rational way of ensuring sound and effective daily operations, and because governmental regulations make them mandatory.

Audits are an important tool in the implementation of "living" management systems. Safety audits are a systematic and planned verification of the safety performance against external and internal requirements. They can be conducted as internal audits or by a third party.

The use of audits within safety management is derived from quality management theories (Kongsvik 2013). International standards for quality management, e.g., ISO 9001 (International Standard Organisation 2015), have been established and are widely used as the basis for certifying enterprises. Accredited certification by an independent third party is a confirmation that the company performs according to the requirements in the standard, and has become a quality stamp that several companies obtain.

2.1 *Internal control of health, safety and work environment (HSE)*

Since 1992, it has been decreed by law that all enterprises under the authority of the Norwegian Labour Inspectorate Agency (LIA) shall work systematically with, and continuously improve the health, safety and environment (HSE) procedures. This implies implementing and maintaining a safety management system at the minimum standard, as described in the internal control regulation. The present version of the "Regulation on systematic health, safety and environment work in enterprises (Internal control regulation)" came into force in 1997, and was last updated in 2014 (Norwegian Ministry of Labour and Social Affairs 1996). The Working Environment Act, which applies for all land based industries as well as the aquaculture sector in Norway, sanctions this regulation (Norwegian Ministry of Labour and Social Affairs 2005).

The internal control regulation's purpose is to ensure that the safety policy and management systems comply with the HSE legislation, and that the internal procedures, laws and regulations are easily available to employees. The companies must document descriptions of HSE functions and responsibilities in the organisation, as well as risk assessments and plans for implementing risk-reducing actions. The employees shall be active contributors and get the sufficient training to be able to do so. The company are supposed to continuously follow up and systematically revise or update the safety management system, and the management must conduct internal audits at set intervals to check the performance of it. LIA will check the documentation of this work during inspections, which will be valuable documentation when investigating accidents. The environmental part is controlled separately by the county administration.

2.2 *The aquaculture legislation and internal control*

The aquaculture industry's obligation to prevent escape of fish, and to report either suspected or known escapes, is stated in the "Regulation on the operation of aquaculture production sites" (Norwegian Ministry of Trade and Fisheries 2008), statutory in the Aquaculture Act (Norwegian Ministry of Trade and Fisheries 2005). Certain parts of this regulation deals with ethical and sound farming of fish and are linked to clauses in the Food Act and the Animal Welfare Act. The Norwegian Food Safety Authority controls these parts.

According to the aquaculture legislation, the companies are obliged to show risk awareness, conduct risk assessments and implement measures to mitigate the identified risks. Furthermore, actions have to be taken if an escape incident happens, by trying to catch escaped fish. There are also requirements on training and competence of the fish farm operators.

Formal requirements on internal control of the aquaculture production are described in the "Regulation on internal control to comply with aquaculture legislation" (Norwegian Ministry of Trade and Fisheries 2004). The system requirements are almost equal to those for the HSE internal control, thus making company management and workers responsible for the safety performance during daily operations. The Norwegian Directorate of Fisheries is the regulatory authority for these requirements, as well as the technical regulations described in the next section.

2.3 *Technical regulations*

The "Regulation on technical requirements to floating aquaculture installations" (Norwegian Ministry of Trade and Fisheries 2011) was introduced to ensure that the standard of fish cages and installations comply with the technical requirements in the Norwegian standard NS 9415 (Standard Norway 2009) for aquaculture production sites. This standard was developed in order to mitigate the increasing numbers of escaped fish due to structural breakdowns or technological failures in the first years of this millennium, and soon proved a success (Jensen et al. 2010). However, escape incidents due to errors, lack of safety barriers or other operational causes, still is a challenge for the fish farming industry.

3 METHODS FOR ASSESSING AND MONITORING SAFETY IN AQUACULTURE

Today, there are few parameters used to systematically measure the safety performance level in Norwegian aquaculture. First, the number of escaped, and suspected escaped, farmed fish is followed closely. The industry has established good routines for reporting in accordance with the authorities' regulations (Norwegian Ministry of Trade and Fisheries 2008), which state that one should report when it is assumed or known that one or more fish have escaped. Furthermore, lice counts are done on a regular basis as defined by the authorities, and levels above 0.5 louse per fish initiate delousing. The delousing operation is identified as critical when it comes to risk for escapes and occupational risk (Thorvaldsen et al. 2015), and increased frequency of delousing should alert the companies to take extra precautions. Serious occupational accidents are reported to the Norwegian Labour Inspectorate Agency (Holen et al, in prep) and the investigations may result in suggestions for preventive actions. Company-internal measures, for example, number of reported nonconformities or near misses, is also likely to correlate with the operators' alertness at work. Still, it can be questioned whether any of these numbers are efficient – or sufficient - indicators for the organisational safety performance in the Norwegian fish farming industry, either nationally or at company level.

The Operational Safety Condition (OSC) method was developed to measure the effect of mitigating actions on operational safety levels over time (Skogdalen et al. 2011). Hence, it may be used for developing safety indicators. Safety indicators are observable measures providing information about safety or the safety level, in an organisation, at a workplace, or during an operation (Kongsvik 2013). Such parameters may be useful in order to develop safety barriers, prioritize and evaluate the effectiveness of preventive measures, or simply satisfy authority requirements with respect to safety management. The overall aim of the OSC development was to reduce the risk of major accidents at offshore installations (Kongsvik et al. 2010).

OSC was introduced as a supplement for assessments of technical conditions on a production facility, i.e., the Technical Condition Safety method (TTS) developed for the oil and gas industry (Ingvarson & Strom 2009). OSC has been developed based on the same basic principles as TTS, which reviews safety critical barriers in maintenance, inspection and design. TTS checks a number of performance indicators related to safety functions that are verified against defined performance standards. A detailed checklist is used to conduct the assessment, and the performance levels are rated according to grades A-F (Skogdalen et al. 2011). As the aquaculture technology advances, the need will increase for systems that monitor the technical safety as well. OSC and TTS supplement each other, and a combination could rationalise the audit processes since several of the underlying safety and risk factors will overlap.

OSC focuses on the "soft" barriers in safety work: Humans and the organisation. The motivation behind OSC was to reduce the risk of major hazards in the oil and gas sector by introducing a method for proactive organisational safety verification and improvement. The core of the method is to compare operational practice against safety requirements (Kongsvik et al. 2010, Skogdalen et al. 2011, Kongsvik 2013). In the Norwegian oil and gas sector, human and organisational factors have to be included in the risk assessments to comply with the health, work environment and safety legislation (Skogdalen & Vinnem 2011). This also applies to the aquaculture industry since the Work Environment Act is regulatory for these workplaces, as well (Norwegian Ministry of Labour and Social Affairs 2005).

Table 1. Steps of OSC method (Kongsvik et al. 2010, Kongsvik 2013).

1. Identify causes for accidents.
2. Which work operations are they connected to?
3. Which organizational conditions/factors are of importance for these tasks?
4. Which internal and external requirements are relevant for each factor?
5. Define checkpoints for each requirement (could be several).
6. Conduct the audit: Evaluate the accordance between the organizational factors and relevant requirements.
    a. Background information: accident statistics, reported accidents, incidents, nonconformities.
    b. Surveys and personal interviews.
    c. Overall analysis, evaluation and reporting. Interpret and describe the organisational safety condition.
    d. Workshop with participants from all levels of the organisation. Generate knowledge and identify measures based on findings in steps above.

OSC is a qualitative method. Interviews with personnel, observations of work procedures, investigations of documents and questionnaires are input to the verification of operational practice versus requirements. The method involves the operators to a great extent and makes them co-owners of the problem, process and necessary changes. The method should be used and managed by company internal HSE personnel. The results should provide information on how organisational factors function and interact with respect to safety. The steps of OSC are listed in Table 1. These are further discussed in the next section.

4 THE OPERATIONAL SAFETY CONDITION (OSC) ADAPTED TO AQUACULTURE

In this section, the results of the preliminary study are summarised. The work has followed the steps listed in Table 1.

4.1 *Step 1 – Identify causes to accidents*

The development of the OSC method is based on identified risk influencing factors with high significance for major hazards (Kongsvik 2013). In this paper escape of farmed fish is defined as the undesired incident. The first step in adapting OSC to aquaculture, according to Table 1, is to identify known accident causes from available information sources, literature and supplementary interviews with personnel. For the case of fish escape, relevant background information about causal factors can be found in escape statistics and reports from the Norwegian Directorate of Fisheries (2016). Furthermore, a number of research reports have been used to identify direct and contributing causes for escape of fish, both technical and structural causalities (Jensen et al. 2010), focus on complex operations (Sandberg et al. 2012), organisational aspects (Fenstad et al. 2009, Størkersen 2012), and human factors and organisational aspects (Thorvaldsen et al. 2015). Structured interviews could also be conducted with workers at fish farms to add to this material when necessary. Table 2 summarises categories of causes and examples of contributing factors to accidents with escape of fish.

Table 2. Some identified causes to escape of fish in Norwegian aquaculture.

Category	Example of cause and contributing factors
Structural/ technological failure	Barrier not functioning – net cage missing or whole in net due to wear and tear, material fatigue or propel caught in net Crane operations – no control of forces
Human-technology interaction	Suboptimal design, allows errors Insufficient user instructions and/or handbook
Operational	Internal control not implemented Understaffing and long working hours – heavy workloads, fatigue Insufficient training of operators Operation planning lacks clarification of responsibilities and abortion criteria Risk assessments are not conducted Communication routines not clarified Poorly described procedures
External conditions	Time pressure Economic pressure Bad weather, heavy winds, waves and strong currents Darkness Insufficient resources, manning, equipment

4.2 *Step 2 – Map work operations*

Previous studies have identified aquaculture operations with particularly high risk for fish escape (Jensen et al. 2010, Sandberg et al. 2012, Thorvaldsen et al. 2015). The most important are: Crane operations, delousing, well boat operations, daily work and maintenance, inspections of mooring lines and net cage, net cage replacement, transfer of fish and feed deliveries.

4.3 *Step 3 – Organisational factors of importance*

The work operations and tasks connected to these causes from step 2 are mapped with organisational conditions that have an impact on the performance or outcome of each task. A description of how each organisational condition affects the work tasks must then be provided, together with a classification of their influence (high, medium, minor). Based on this, a list of organisational factors with high influence on the operational practice is developed. Kongsvik et al. (2010) have identified seven overall factors based on a literature study:

1. Work practice
2. Competence
3. Procedures and documentation
4. Communication
5. Workload and physical environment
6. Management
7. Change management

Regarding the organisational conditions of highest relevance for the work tasks, we approached the task by evaluating the seven organisational factors listed by Kongsvik et al. (2010) against the operational challenges identified in aquaculture operations hazardous with respect to fish escape (step 2, section 4.2). Figure 1 illustrates the preliminary results, which show that the organisational factors identified for the oil and gas sector applies to the fish farm operations. In Figure 1, arrows are drawn to show examples of dependencies between operational factors (right) and work operations (right).

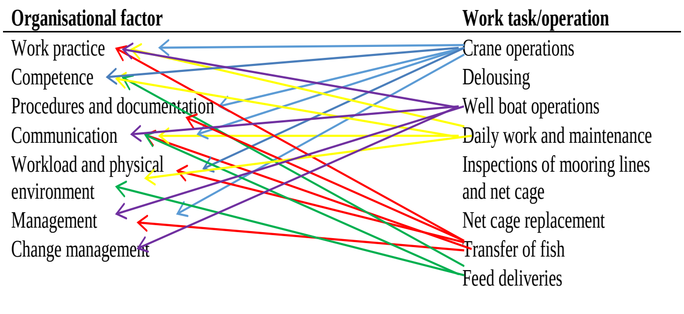

Figure 1. Dependencies between organisational factors (Kongsvik et al. 2010) and aquaculture operations with a high risk of fish escape.

4.4 *Step 4 – Internal and external requirements*

Step 4 is to establish safety performance, internal and external requirements relevant for each condition mapped. These can be found in company internal policy documents and procedures, or in authority regulations. An initial assessment has been performed for the seven organisational conditions with respect to operations with a high risk of escape. In Table 3, we have listed examples of relevant requirements and suggested checkpoints (step 5, next section), as well as suggested sources for identification of requirements. The requirements should be found both in regulatory (mandatory) regulations, as well as company internal regulations. Due to limitations in space, only a few of the factors are shown in Table 3. For example, related to work practice, all employees should be familiar with the operational procedure and also acknowledge that they know it by placing their signature on it. Further examples are shown in Table 3.

4.5 *Step 5 – Define checkpoints*

Finally, step 5 in the development process is to identify checkpoints in order to assess whether the organisational condition complies with the requirements. Some of the checkpoints can be developed into safety indicators, or be included in safe job- analyses to be performed prior to operations with significant risk for accidents. The present Table 3 (next page) is not comprehensive and should be developed further to establish a complete basis for safety audits in aquaculture companies.

4.6 *Step 6 – Conduct the audit*

The resulting list of organisational factors, requirements and checkpoints then forms the basis for interview guides and/or questionnaires to be used in the safety audit. The audit should reveal both weaknesses and strengths of the organisation, and include personnel at all levels. For fish farming companies this should involve representatives from top management, HSE managers and personnel, fish farm operators and operational managers.

5 DISCUSSION

Preventing fish escapes have been the main motivation for improving and implementing performance requirements for aquaculture technology and structures. The effect of these measures is mainly evaluated in terms of reduction in escapes, both regarding number of incidents and number of fish. The escape reports the last decade show that in relation to the increase in total production of farmed fish, the number of escapes are considerably reduced. Nevertheless, escape of farmed salmon is still a major hazard in the aquaculture industry due to serious consequences for the ecosystem (wild salmon), industry reputation, and financial losses.

Table 3. Examples of relevant requirements and checkpoints for the two organisational conditions "work practice" and "competence" in aquaculture operations.

Organisational factor
- Source to identify requirements
  - Requirements
    - ✓ Checkpoints

Work practice
- Internal quality and safety management system
- Policy documents
- Interviews
- Certifications e.g. Aquaculture Stewardship Council (ASC), ISO 9001, OSHAS 18001
- Regulatory requirements
  - All employees should know the procedures and sign it.
  - All personnel shall be trained according to the requirements in the management system.
  - Internal control Aquaculture: hazard identification, risk assessments and develop action plans, preventive measures
    - ✓ Are all operations described in the management system?
    - ✓ Are risk assessments and evaluations performed for all tasks?
    - ✓ Are the procedures for use of personal protective equipment described?

Competence
- IK Aquaculture
- Internal quality and safety management system
- Work procedures, skill requirements
- Certifications e.g.Aquaculture Stewardship Council (ASC), ISO 9001, OSHAS 18001
  - The personnel know the purpose and content of the internal control procedures.
    - ✓ Does the company have a procedure which describes the competence and skills required?
    - ✓ Are the competence requirements clearly defined in the management system?
    - ✓ Are safety training conducted for operators?
    - ✓ Is the education and training of the employees documented?

Methods have been developed in other industries in order to be able to measure risk development at workplaces. The Petroleum Safety Authority Norway (PSA) established in 1999 the RNNP project to develop a method for monitoring the risk levels in the petroleum activity on the Norwegian continental shelf. The goal is to control the major hazard risks for workers on offshore installations (Vinnem et al. 2006), and RNNP contributes to a shared understanding of risk development between industry companies, unions and authorities (PSA 2016). Since the pilot study in 2001 annual updates have been performed. It consists of both quantitative and qualitative methods that are complementary to each other. RNNP is now established as an important management tool for all parties in the oil and gas sector. Similar tools could thus be relevant also for the aquaculture sector.

A recent study on the escape of fish and influence of organisational aspects shows that organisational factors are significant contributors to the escape accidents (Thorvaldsen et al. 2015). When the safety barrier is lacking or not functioning because of holes in the net, a direct contributing factor is that the net cage handling has been incorrect. The root causes may be lack of sufficient training, competence or heavy workloads. Other contributing factors have found to be lack of communication or (non-reported) nonconformities in the operational procedures. A recommended way forward would therefore be to develop tools to ensure that the state of the organisational conditions and factors within the fish farming companies is checked regularly.

The development of OSC was based on a need to systematically and qualitatively measure the operational safety performance at process plants or offshore installations, as a supplement to technical safety as a means to identify where improvements are required. The aim of the method is to set a performance standard for the organisational risk controlling systems and evaluate how well they function as operational safety barriers (Kongsvik et al, 2010). OSC is thus likely to be applicable to other production industries where human and organisational factors have significant impact on the safety levels in the operations, as in the fish farming industry.

There is also a need for establishing effective safety indicators that give a prewarning if the risk for fish escape. Today, the safety indicators are lagging in the form of number of escaped fish. The information gathered using the OSC method could probably be used to develop organisational safety indicators that address specific safety challenges in companies, regions or locally at a fish farm. A good approach could be to start with the regulatory requirements for internal control that are mandatory and known to the company management.

The performance of safety management systems in the aquaculture industry shall be audited regularly as a part of the internal control. Regulatory authorities conduct inspections at intervals, and they have the policy to do so-called risk based audits, i.e., they will check the parts of the management systems that is relevant for the known major risks in the industry. At the time being, this includes procedures and operations that are associated with risk of fish escape and lice treatments. The internal control often reflects this in practice, as the companies aim to be up to standard during the audits. Furthermore, easily available parameters are most likely to be inspected, for example, written procedures, nonconformity reports or equipment maintenance. The correlation between a net cage which is not properly installed and organisational factors is not obvious, and such an error is a result of the interaction between humans, technology and organisational factors. This supports the use of methods like the OSC that takes a more holistic approach.

The seven organisational conditions identified to reduce the risk for major hazards in the oil and gas industry (Kongsvik et al, 2010), seems to be relevant also for the aquaculture industry. OSC goes into the depth of the problem and provides an assessment of the organisation as an entity, and covers different authorities' regulations. This allows an overall approach which is useful for the company's quality management activities. The information gathered during the audit forms the basis for development of necessary operational changes. The improvements are discussed jointly by all parts of the organisation, and this kind of dialogue between operators and top managers is catalysed using OSC. The process is resource-demanding and requires considerable man-hours from process leaders and employees. Ownership and understanding among the operators dealing with the challenges daily ensure that the most effective preventive measures to be developed. It is likely, however, that the fish farms along the Norwegian coast are quite similar with respect to organisational conditions, and OSC could therefore be developed as a joint effort across the key players in the industry. Parts of the OSC can be repeated at intervals and thus provide key information on safety performance useful for the company's management, but also for the regulatory authorities. The results could be used to establish safety indicators on safety performance at industry level, similar to the oil and gas sector through the RNNP project. Minor adaptations in the safety audit checklists could subsequently be conducted within each company. This would represent a significant contribution to improving the safety levels in the fish farming industry

6 CONCLUSIONS

This paper presents a knowledge basis for adapting the Operational Safety Condition (OSC) method to the aquaculture industry. During the last 10 years the industry has accomplished a great reduction in the number of escapes due to escape incidents caused by technical failures in constructions and equipment. The next step is to improve the organisations and management systems at the fish farms in order to reduce the organisational risk factors in the aquaculture industry and avoid "human errors".

This paper presents a knowledge basis for adapting the qualitative method called Operational Safety Condition (OSC) to the aquaculture industry. Part of the method is to develop a detailed checklist, tailored according to the requirements identified for each organisational safety condition. The pre-study demonstrates that OSC seems to be a promising tool for audits of the organisational safety conditions in aquaculture companies.

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