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Market Potential and Buyer Criteria for a New Transportation System for Whole Fish: The Norwegian Salmon Farming Industry

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Abstract
Peter Stette AS is developing a system for transportation of fish in cooperation with Picker Technologies LLC. Key feature is swift transportation of fish without the use of water, hence low energy consumption. The pace of transportation is determined by vacuum and air flow, theoretically meaning that lift height and weight is unlimited. Several potential applications have been discussed with the salmon aquaculture industry. The one application perceived as having the greatest potential is that in internal transportation of fish at processing plants. It is important that the system is able to register data on size, weight, *etc.*, as well as having some sort of counting mechanism. The most important issue to solve is how transportation of live fish in a dry environment will affect fish welfare. Both industry and responsible authority emphasize this. Other issues of concern are hygiene effects, maintenance requirements, stability and durability, all of which will have to be dealt with properly in order to appeal to the industry. The common perception is undoubtedly that there is a need for new transportation solutions in the Norwegian salmon aquaculture industry. Information obtained in this project gives Peter Stette AS a unique opportunity to head start and to develop a tailor-made solution to industry needs.

PREFACE

The project "Market Potential and Buyer Criteria for a New Transportation System for Whole Fish: The Norwegian Salmon Farming Industry" is a collaboration between the research institute Møreforsking AS and the manufacturer Peter Stette AS. The background for the project is a notion of a need for new transportation solutions in the aquaculture industry.

Researcher Bjørn Tore Nystrand (Møreforsking AS) has been the project leader, while Peder Stette (Managing Director, Peter Stette AS) has been responsible from the manufacturer's side. Jan Egil Frøysland and Tore Sylte (both Sales, Peter Stette AS) have contributed in conducting interviews of players in the salmon aquaculture industry. Todd Deligan (Vice President, Picker Technologies LLC) have participated in designing the survey. Research assistant Marianne Lindhjem Staurset (Møreforsking AS) was involved in compiling an overview of the Norwegian salmon aquaculture industry with regards to slaughterhouses. Thank you all for your contributions!

The project has been highly dependent on first-hand information from the salmon farmers and processors. Big thanks to the informants in this project.

Kristin Sæther (The Norwegian Seafood Association), Anita Nygård Reistad (Directorate of Fisheries), Berit Storbråten (Statistics Norway) and Anne Kjersti Austgulen (Norwegian Food Safety Authority) have all contributed with their knowledge regarding salmon aquaculture in Norway. Thank you!

The project has been financed by The Research Council of Norway's VRI program. Competence broker Wenche Emblem Larssen (VRI Møre & Romsdal) has been the main contributor in the initiation process and deserves credit for establishing the project.

Ålesund 21.06.2011

Bjørn T. Nystrand

Bjørn Tore Nystrand
Project leader

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SUMMARY

Peter Stette AS is developing a system for transportation of fish in cooperation with Picker Technologies LLC. Key feature is swift transportation of fish without the use of water, hence low energy consumption. The pace of transportation is determined by vacuum and air flow, theoretically meaning that lift height and weight is unlimited.

Several potential applications have been discussed with the salmon aquaculture industry, which has revealed some applications with greater potential than other. The one application perceived as having the greatest potential is that in internal transportation of fish at processing plants. It is important that the system is able to register data on size, weight, *etc.*, as well as having some sort of counting mechanism. The most important issue to solve is how transportation of live fish in a dry environment will affect fish welfare. Both industry and responsible authority emphasize this. Other issues of concern are hygiene effects, maintenance requirements, stability and durability, all of which will have to be dealt with properly in order to appeal to the industry.

In addition, numerous ideas for other applications within the fishing and aquaculture industry have been brought up by industry players. These will constitute a basis for the further development process.

The common perception is undoubtedly that there is a need for new transportation solutions in the Norwegian salmon aquaculture industry. Information obtained in this project gives Peter Stette AS a unique opportunity to head start and to develop a tailor-made solution to industry needs.

1 INTRODUCTION

Peter Stette AS (Stette) is a manufacturing company and a key supplier to the food processing industry, both domestic and worldwide. Stette and the American company Picker Technologies LLC are developing a new transportation system for whole fish. By means of pressure differences between membranes in a tube, the fish will move. With proper development, the system may have numerous applications within the aquaculture industry, both on land and sea.

1.1 Stette Transportation System

The transportation system consists of a tube with one open end and one end connected to a vacuum chamber. Inside the tube, membranes with a fixed interval adapted to the size of the fish are installed. The membranes are flexible in order to enclose the fish and to gently transport it. With atmospheric pressure in the rear and vacuum in the front end, the fish will move from one membrane to another, maintaining the differential pressure on the front and back. The speed of the fish is determined by vacuum and air flow, theoretically meaning that lift height and weight is unlimited.

The energy consumption is reduced substantially compared to existing modes of transportation. The system will also provide a high degree of flexibility in application and installation. Hygienic membranes which easily can be removed and replaced are under development, making maintenance and disinfection of both the membranes and tube possible.

Stette is looking into the possibility of integrating a grader system which will scan each fish on its way through the tube. The idea is to sort the objects by weight, size, color, condition, *etc*. The company also focuses on developing cleansing systems (CIP) [1], switches, receivers, connections to other equipment, *etc.* in order to make the system as applicable as possible.

The development is in an early phase, and many adaptations remain until the system is commercially available in the fishing industry. A simplified prototype of the system was however showcased at Nor-Fishing 2010, demonstrating the principle of it, *i.e.* transportation of whole fish without large amounts of water and with low energy consumption.

Below is a 3D illustration of how the developers envision the system in transportation between the cage / slaughter pen and the processing plant, with one tube going directly to the silage site (Fig. 1-1).

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[1] Clean In Place

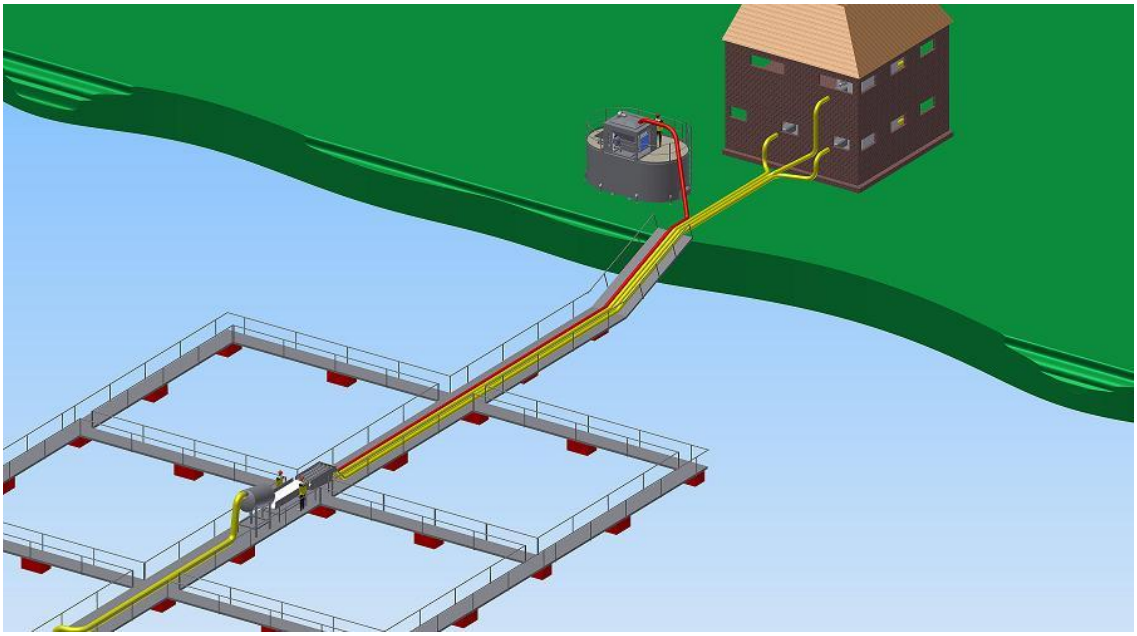

Figure 1-1 Transportation between cage and processing plant with one tube connected directly to the silage site (illustration by Peter Stette AS©2011).

1.1.1 Applications

1. *Transportation of dead fish from marine cages to silage system.* Dead fish is today usually brought to the surface using lift-up systems which collects the fish on the edge of the cages. From here it is transported manually to the silage site using tanks and boxes. Such operations represent a risk to operators who handle the lift and other equipment, and further a risk of infection. The task also requires more people in action.

   The new system makes it possible to bring a tube from the silage site to the cage edge, where the dead fish is transported directly to the silage system through the flexible tube. The tube can be wrapped together onboard vessels for easy access in case of dead fish outbreaks. Also, to make the system complete, the idea is to integrate a scanner which counts, weighs, and measure size and color *etc.* when registering dead fish.

2. *Internal transport in processing plant.* The system may be integrated with other equipment affiliated to gutting, slaughtering, bleeding, *etc*. Transportation occurs in a closed atmosphere, without limitations regarding whether it takes place inside or outside, high or low. Fish is currently being transported on conveyor belts with major hygienic and maintenance challenges. A logistics system with membrane tubes will solve many of these. The system can gather data from all fish that pass. Based on these data, fish can automatically be directed to its appropriate destination. The entire system is CIP cleaned by day's end, and the affected surface will be minimal compared to current conditions.

3. *Transportation of by-products.* The system is fairly gentle, which might open for transportation of delicate raw material, *e.g.* eggs and liver. This application has not yet been tested, but trials with strawberries and grapes have been conducted with promising outcomes.

4. *Transportation onboard vessel.* Small spaces and limited production facilities onboard vessels makes Stette's new flexible system highly appropriate. The onboard transportation is in general based on vacuum pumping in water and carriers. With this new system, greater flexibility is achieved and fish can be transported regardless of space and height.

5. *Direct slaughter of farmed salmon.* Experiments on harvesting at the cage site (dead-haul) have shown successful results as regards to both fish quality and welfare. Some of the advantages of dead-haul are improved hygiene in closed transport, elimination of transport fatalities caused by high sea temperatures and weak fish, improved fish welfare, and completely chilled fish delivered to the processing plant (Midling *et al*., 2008). The transportation system under development may apply to dead-haul harvesting in closed transportation from cage to plant.

1.2 The Norwegian aquaculture industry

Aquaculture in Norway dates back to 1850 when the first brown trout (*Salmo trutta*) were hatched. The first successful on-growing of Atlantic salmon (*Salmo salar*) took place in the early 1960s. Ten years later, a technological breakthrough came when the first cage was constructed. On-growing in cages proved to be safer and provided much better environmental conditions than onshore tanks or the various enclosures that had been used earlier, particularly with regard to salmon farming. Today, salmon and rainbow trout (*Oncorhynchus mykiss*) farming has developed into a major business along the majority of the Norwegian coast (FAO, 2005). This is illustrated in Fig. 1-2.

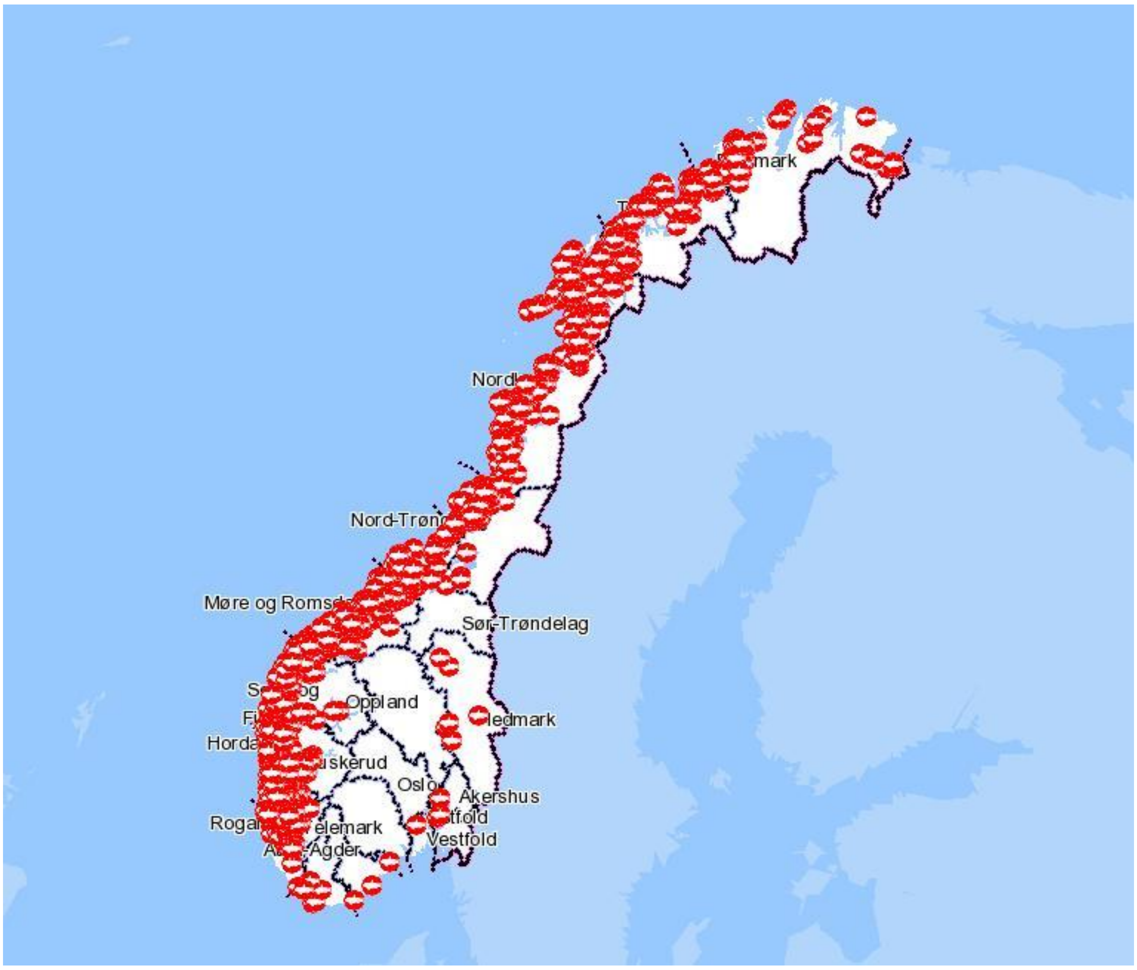

Figure 1-2 Approved sites for farming of salmon, brown trout and rainbow trout in Norway. Juvenile and grow out sites (source: Directorate of Fisheries).

The Norwegian farm industry has continued to grow since the very beginning, and is today a world leader in the globalization of the international seafood market. The industry is characterized by a few multinational companies; from 1994 to 2008 the number of companies has declined by 60 %, while the number of licenses has increased by 28 % (Liu *et al.*, 2011).

Globally, 1.46 million tons Atlantic salmon was produced in 2010. Norway's share amounts to 65 % or 944,600 tons, making it the largest producer in the world. Of this, 922,000 tons was exported to near 100 countries worldwide. The export value was 31.3 MNOK (Bessesen, 2011).

2,930 persons were employed in production of salmon and rainbow trout for food (on-growing) in 2009, an increase of 34 % since 2005 (Statistics Norway, 2010).

Norwegian aquaculture is regulated by Act No. 79 of 2005 relating to aquaculture (Aquaculture Act), stating that *"(...) no person may engage in aquaculture activities without registration as the holder of an aquaculture license in the aquaculture register (...)"*. The Aquaculture Act applies to the production of aquatic organisms, and the license permits the production of specific species in limited geographic areas (sites). For a thorough review, see the Aquaculture Act. In accordance with regulations, sites with grow out and brood stock salmon are to be drained and fallowed for a minimum of two months after each production cycle (Decree no. 822 of 2008 relative to the operation of aquaculture installations).

In Fig. 1-3, the value chain for salmon aquaculture is illustrated. The stippled box refers to the focal point in this project.

Figure 1-3 Salmon aquaculture industry's value chain (simplified) (source: Frisvoll, 2003; Marine Harvest, 2010).

2 MATERIAL AND METHODS

2.1 Stage I – Identifying potential domestic users

Based on available national registry data, estimates of potential users in the Norwegian salmon aquaculture industry are made. Aquaculture facilities, slaughterhouses and processing plants are included. They will be listed by county and sorted by type of business, and will constitute the scope of potential users for further data collection (Stage II).

2.2 Stage II – Identifying applications and buyer criteria for the transportation system within the Norwegian salmon aquaculture industry

The project will focus on the Norwegian salmon aquaculture industry, and the sample will consist of large and medium-sized companies. Based on the identification in Stage I, Stette and Møreforsking AS will determine sample size and select participants for further data collection. A non-probability convenience sampling strategy, based upon properties as company size, number of licenses and sites, and geographical location is executed. Data is collected via:

- **Questionnaires.** A self-administered questionnaire (fillable PDF form) via e-mail will be distributed to the sample. The participants will be given a product description and presented with a video of the system in use. Questionnaire and product description are developed in cooperation with Stette.
- **Interviews.** A handful of interviews with some of the respondents will be conducted, either via telephone or personal interview. The objective is to gather more specific information on how to further develop the transportation system in accordance to the industry's needs and criteria. Questions are formulated by Møreforsking AS and Stette together.

The data collection will focus on:

- Potential applications
- Range and flexibility
- Dimensions and system capacity
- Maintenance and stability
- Other buyer criteria

Based on the results, the most relevant users and applications will be defined. The results will further provide essential information to the product development process.

2.3 Data analyses

Descriptive statistics based on quantitative data from the questionnaires are conducted using Microsoft Office Excel 2010. Interviews are transcribed and translated, and reported anonymously.

3 RESULTS

3.1 Stage I – Identifying potential domestic users

According to available statistics from the Directorate of Fisheries (DF 1) there were a total of 991 grow out licenses for Atlantic salmon and rainbow trout in 2010[2]. The two major counties are Nordland and Hordaland, with 160 (16.1 %) and 157 (15.8 %) licenses respectively. The Directorate of Fisheries reports 1,023 grow out sites in sea water regarding salmon, rainbow trout and trout in 2010[3]. Licenses and sites are distributed between 182 companies (incl. brood stock and R&D). Overall, 124 slaughter and packaging plants had permission for slaughtering and processing farmed fish in 2009[4] (The Norwegian Food Safety Authority – NFSA).

3.1.1 Aquaculture facilities

After a review of the Directorate of Fisheries´ register[5], a total of 987 *commercial* licenses for grow out salmon farming (incl. slaughter pens), distributed on 1,049 sites and between 174 companies are found (DF 2). To ensure that the companies operates within the relevant industry (salmon farming), an industrial classification based on each company's NACE code was made. Companies classified by the code 03.211 (Operation of marine fish farms)[6] constitute the scope (see Mørkve & Ulvan, 2010). The procedure resulted in a total of 133 salmon farming companies, holding 940 licenses. The licenses are further spread over a vast number of sites along the coastline, operated exclusively by one or several companies in cooperation.

In Tab. 3-1, license distribution in column three is associated with the license holders' geographic location, regardless of which county the license is being used. Sites are though associated to its actual location. Figures refer to sites approved, not considering fallowed sites, *i.e.* not all sites are in use simultaneously.

[2] Figures per 27 January 2011
[3] Figures per 27 January 2011
[4] Figures per 26 July 2010
[5] Updated 6 December 2010
[6] Production of grow out fish, mollusks, crustaceans and echinoderms in coastal and marine based aquaculture

Table 3-1 The Norwegian salmon farming industry in numbers; grow out (Source: Directorate of Fisheries)

	Per 6.12.10		
	Companies	Licenses	Sites
County	**No.**	**No.**	**No.**
Finnmark	3	39	64
Troms	14	78	111
Nordland	33	171	194
Nord-Trøndelag	6	39	68
Sør-Trøndelag	12	96	79
Møre og Romsdal	10	75	101
Sogn og Fjordane	13	33	84
Hordaland	34	380	194
Rogaland	5	26	66
Vest-Agder	1	1	11
Aust-Agder	2	2	2
Total	**133**	**940**	**974**

Marine Harvest Norway AS is by far the largest company (HQ in Hordaland), holding 209 licenses (grow out and slaughter pen). Another major company is Lerøy Seafood Group ASA, which holds a total of 106 grow out licenses distributed between the four subsidiaries Lerøy Aurora AS (18 licenses), Lerøy Hydrotech AS (23 licenses), Lerøy Midnor AS (31 licenses) and Lerøy Vest AS (34 licenses). Mainstream Norway AS and Salmar Farming AS, the third and fourth largest companies, hold 45 and 43 licenses respectively. The major salmon aquaculture companies have local subdivisions spread along the Norwegian coastline in connection to their sites. In selecting companies for Stage II, these subdivisions are taken into account.

The major companies have slaughter and processing plants incorporated in their business and value chains. Several independent plants exist as well. It has not been feasible to obtain a complete list of licensed salmon slaughterhouses and processing plants, neither from NFSA nor others. The data regarding this sector of the industry are therefore somewhat uncertain. As mentioned in chapter 3.1, there were a total of 124 plants in 2009. This figure does not differ between species, thus making it difficult to distinguish salmon from other species. However, NFSA claims that it is likely that the majority of the plants are associated with salmon. The figure for 2010 is yet to be publicized.

Table 3-2 Approved slaughter and packaging plants 2009 (Source: NFSA)

County	Slaughter and packaging plants 2009
Finnmark	10
Troms	12
Nordland	29
Nord-Trøndelag	6
Sør-Trøndelag	11
Møre og Romsdal	19
Sogn og Fjordane	7
Hordaland	21
Rogaland	4
Remaining counties	5
Total	**124**

NFSA has provided a somewhat incomplete list of slaughter and processing plants for 2010[7]. A total of 115 plants are listed, many of which are also found in the Directorate of Fisheries` register over aquaculture license holders.

As Tab. 3-1 and 3-2 shows, salmon aquaculture in Norway is a quite substantial industry.

3.2 Stage II – Identifying applications and buyer criteria for the transportation system within the Norwegian salmon aquaculture industry

The initial sampling process resulted in a total of 63 questionnaires being distributed to regional directors, operations managers, facility managers, CEOs, *etc.* Due to low response rate, it was decided to expand the sample. The final sample consists of 102 respondents, some of which represents the same company but different subsidiaries and / or hierarchic positions. Reminders were sent out on two occasions; one week and two weeks subsequent to the first distribution.

Interviews were conducted with six companies and subsidiaries based upon answers given in the questionnaire. Informants were the same as who had answered the questionnaire.

[7] Dated 8 December 2010

3.2.1 Questionnaire

A total of 24 questionnaires were obtained (response rate 23.5 %). The questionnaires are coded into a database in Microsoft Office Excel, and descriptive statistics are run (means) and presented. The questionnaire also contains open ended questions, and a summary of the answers are given in Tab. 3.3.

Impression of Stette as a supplier of equipment (Qi) was measured on a five-point semantic differential scale ranging from "very good" (2) to "very bad" (-2), with a sixth alternative "do not know them". Two respondents have no knowledge of Stette and are therefore discarded when calculating the mean. One respondent have a negative impression, while three respondents have neither a positive nor negative impression. All of the remaining 18 respondents have a positive impression of Stette as a supplier of equipment. Mean score is **.86**.

Immediate impression after having watched the video (Qii) was measured on a five-point scale ranging from "very compelling" (2) to "not compelling" (-2), with a sixth alternative "do not know". With the exception of four respondents, the immediate impression is either neutral or positive. Mean score is **.42**.

Potential in exploiting the technology in the fish farming industry (Qiii) was obtained on a three-point scale ranging from "great potential" (2) to "no potential" (0), with a fourth alternative "do not know". Two respondents do not know (discarded), and another one does not see any potential. The remaining 21 sees some to great potential in exploiting this technology. Mean score is **1.14**.

Regarding ***applicability (Qiv 1-4)***, four questions were formulated and measured on five-point semantic differential scales, ranging from "very likely / very interesting" (2) to "very unlikely / very uninteresting" (-2), with a sixth alternative "do not know". The question regarding the likelihood of using the system in handling of dead fish (Qiv1) has a mean score of **.14**. The likelihood that the system is integrated in slaughterhouses (Qiv2) has a mean score of **.20**. Interest in using the system in direct gutting of the fish (Qiv3) got a mean score of **.37**, while interest in using the system for internal transportation at a processing plant (Qiv4) got a mean score of **.76**.

Importance of the system's ability to register data on size, weight,* etc*. (Qv) was obtained on a three-point scale ranging from "very important" (2) to "not important" (0), with a fourth alternative "do not know". One respondent did not answer this question (discarded). Except for one respondent stating do not know (discarded) and two finding it not important, the importance of the system's ability to register data is considered important to very important with a mean score of **1.32**.

The need for new transportation solutions in the fish farming industry (Qvi) was obtained on a four-point scale ranging from "needed very much" (4) to "not needed" (0), with a fifth alternative "do not know". The need for new transportation solutions is considered to be large for most of the respondents, giving a mean score of **2.00**. One respondent answered do not know.

Thoughts on ***implementation (Qvii)*** were measured on a five-point semantic differential scale ranging from "highly appropriate" (2) to "highly inappropriate" (-2).

The mean score is **.42**; 11 finding it appropriate, 12 finding it neither appropriate nor inappropriate, and one finding it inappropriate.

A summary of means are given in Tab. 3-3 below.

Table 3-3 Summary of means

Scale	Mean scores									
	Qi	**Qii**	**Qiii**	**Qiv1**	**Qiv2**	**Qiv3**	**Qiv4**	**Qv**	**Qvi**	**Qvii**
Very good - very bad	.86									
Very compelling - not compelling		.42								
Great potential - no potential			1.14							
Very likely - very unlikely				.14						
Very likely - very unlikely					.20					
Very interesting - very uninteresting						.37				
Very interesting - very uninteresting							.76			
Very important - not important								1.32		
Needed very much - not needed									2.00	
Highly appropriate - highly inappropriate										.42

Qi (n=22), Qii (n=24), Qiii (n=22), Qiv1 (n=22), Qiv2 (n=20), Qiv3 (n=19), Qiv4 (n=21), Qv (n=22), Qvi (n=23), Qvii (n=24)

10 respondents have answered correctly on the question regarding the *five most important issues when deciding upon using / buying the system*. It may seem that there have been some problems with the formatting of the questionnaire as regards to this question solely. Nevertheless, all the 10 correctly filled out questionnaires concerning this question rate “Gentle handling of the fish” as important, seven of them as the most important issue. “Hygiene”, “Stability”, “Simple maintenance” and “Durability” are also issues considered important. Due to the fact that only 10 respondents have answered this question, care must be taken in interpreting the outcome.

As regards to the open ended questions, a summary in the format of bullet points are presented in Tab. 3-4 below. The feedback are interpreted and translated, and placed in the proper category in the table (some respondents wrote all the answers in one box, not considering the initial split between ideas, pros, and cons / concerns).

Table 3-4 Ideas for applications, pros, and cons

Ideas for other applications within the fishing industry
• Long transport routes, between buildings • Live fish between cage and barrel (juveniles) • Lice flusher on the steps, possible application? • Transportation of frozen fish and fish meat between divisions • Onboard customized vessels handling high mortality in a closed system (closed transportation almost from the cage bottom to grinding) • Transportation of gutted/opened fish • Mobile and digitalized solution easy to hoist down onto the feeding vessel for connection to pipe gate (in and out). Estimated reduction in time consumption is 50 %, as well as the operations will be less personnel demanding. Fish then can be scanned and data on weight, condition, defects, and lice counts can be obtained. • Uptake of fish from the cage by an emergency situation • Non-consumer goods (*e.g.* dead fish, trimmings)
Pros
• Ability to easily scan and register each fish in a relatively dry environment • Automatically directing the fish to its proper destination / production line • Transportation of a single fish at a time • Low stress factor • Flexibility • Efficient and quick • Easy • No water usage • Solid and reliable counting and scanning of each fish • Dead fish handling
Cons / concerns
• Cleansing of the tube's inside • Skepticism regarding operation, maintenance and hygiene • Fish welfare issues • Capacity issues, large volumes • Anesthesia by the cage edge • Hygiene and cleaning issues • Quite ungentle treatment of the fish • Capacity and welfare of live fish • Cleansing of the membranes

Some respondents express that the video provides inadequate information about how the system functions. Due to this, some had trouble answering questions about pros and cons. Nonetheless, the information obtained is vital for the further development process. Elaborations to the information from the questionnaires are acquired via interviews, and are presented in chapter 3.2.2.

3.2.2 Interviews

The interviews conducted as a follow-up of the questionnaires has provided additional information regarding challenges, pros, applications, buyer criteria and current transportation solutions. The following questions were asked:

1. What challenges / advantages do you see regarding the system that Stette is now developing in transportation of *live fish*?
2. What challenges / advantages do you see regarding the system that Stette is now developing in transportation of *gutted / fileted fish*?
3. Applications
    a. Where in your production do you see the greatest potential for this system?
    b. Can you think of other potential applications in the aquaculture industry?
    c. What about applications in other parts of the fishing industry?
4. Buyer criteria
    a. What will be the decisive factor(s) in deciding upon buying the Stette transportation system?
    b. Which qualities are necessary for this solution to be superior to existing transportation systems?
5. Which transportation solutions do you currently use?
    a. At what cost did this / these solution(s) amount to?
    b. What shortcomings do you experience that the current transportation system has?
6. Do you have any other comments?

The main challenges in transportation of live fish are fish welfare, maintenance / cleansing and hygiene. One point out that Listeria infection needs to be prevented. Orientation of fish into the tube (*e.g.* tail first), seasonality regarding temperature fluctuations, and mechanical abrasion are also mentioned as potential challenges. Cleansing of membranes and tube smudged with slime and lice are seen as a potential challenge, or at least as an operation which needs proper solving. In transportation of gutted / fileted fish, no clear challenges beside those mentioned for live fish are expressed. The fish welfare aspect of the operation is no longer an issue. One is nonetheless concerned about downgrading of fish, and states that this system will not work properly with fileted fish. Capacity concerns are also brought up as a potential deficiency.

Regarding advantages in general, energy consumption is key. If proven to be less energy intensive, the industry may experience a growth in turnover due to cost reductions. Space savings and less maintenance are also perceived as advantages with this system.

Applications in connection to slaughterhouses are perceived to have great potential, particularly in internal transportation over shorter distances. An advantage in such operations is transportation which does not require water usage. Internal transportation between slaughtering, fileting and other equipment are mentioned as well. Dead fish handling and counting of fish are two other applications with alleged potential.

Other potential applications are in counting of lice at the processing plants / fish farms. Combined with some sort of photographing one can count the lice on the photo. The time spent out of the cage will be minimal, thus making anesthesia of fish unnecessary.

Also in transportation of juveniles this system may have potential. Lots of juvenile fish is transported, and the opportunity to sort the fish in the same operation is perceived as an advantage. Another potential application is in the food industry; the system will reduce water consumption and thus energy consumption, and might also deter bacterial growth. One has brought up the question whether this system may be suitable for transportation of frozen fish as well.

Buyer criteria highlighted are fish welfare, cost, energy consumption, capacity, maintenance and flexibility. In order for this system to be superior to existing modes of transportation, the fish welfare aspect is crucial. The system also needs to be more stable and durable, *i.e.* less problematic than conveyor belts which easily get stuck and break. The quality of the end product will also have to be upheld.

The most common transportation systems in operation today consist of conveyor belts, vacuum pumps / c-flow pumps, siphon systems, and different kinds of drainage channels / gutters and tanks (dead fish). Forklifts and jacking trolleys are also being used. Shortcomings in current transportation systems are lack of control regarding number and size of fish, as well as fairly ungentle treatment. Vacuum pumping of fish may in some cases harm the fish severely, and thus downgrading the product. Conveyor belts also have a tendency to easily break, which shortens its longevity and causes delays in production. Another deficiency is that it is space and maintenance demanding.

4 DISCUSSION

The fish farming industry needs new transportation solutions. The potential in exploiting the technology which Stette is developing for transportation purposes is considered to be quite promising. Issues regarding fish welfare though are of utmost importance if the industry is to implement the technology, as well as hygiene effects, stability, maintenance and durability.

Four potential applications was presented to the aquaculture industry players; dead fish handling, integration in slaughterhouses, direct slaughtering, and internal transportation. Of these four, internal transportation is considered most interesting. An issue to be further investigated is transportation of live fish in a dry environment. This issue has been discussed with the Norwegian Food Safety Authority, who refers to chapter 4 in Decree No. 1250 of 2006 relative to slaughterhouses and processing facilities for aquaculture animals. The legislation emphasizes the well-being of the fish, and that new methods and technical solutions should be tested and found acceptable prior to use. This may be interpreted as if the fish welfare is maintained and documented through proper testing, the transportation system should be found acceptable.

Moreover, ideas for applications other than the aforementioned include use onboard customized vessels handling high mortality, transportation of gutted fish, non-consumer goods and frozen fish and fish meat, and uptake of fish from cages in an emergency situation. These applications will also be evaluated in the ongoing development process.

Several express concern about hygiene issues and fish welfare. These are topics which have to be taken into account and properly solved prior to a future launch. On the other hand, many pros are also being mentioned. Keywords are transportation of a single fish at a time, flexibility, efficiency, quick, easy, no water usage, scanning and registering each fish, and automatically directing fish to its proper destination. This feedback will be essential in developing a superior transportation system.

The next phase will include sorting and prioritizing applications perceived to have the greatest potential, and further to develop a prototype and conduct testing in order to document the system's properties as regards to fish welfare, hygiene effects, energy consumption, *etc*. Testing should be conducted in cooperation with the salmon aquaculture industry under supervision by the Norwegian Food Safety Authority, who is "*(…) responsible for all legislation within the production and distribution of food (…)*" in Norway (NFSA 1). A close cooperation between producer, industry and authority is considered to be a beneficial procedure to ensure that further development occurs in accordance with industry needs and authority demands (*e.g.* to ensure fish well-being).

The low response rate however makes it inconvenient to generalize the findings to apply to the Norwegian salmon farming industry as a whole. Nevertheless, vital information from key industry players has been obtained and will constitute an important basis for the further development.

Since this project was first initiated, Stette and Picker Technologies LLC have improved several key issues brought up by the industry. It is still a work in progress and adjustments are continuously being made, concentrating on maintenance, hygiene and fish welfare issues in particular. Tests are being conducted in order to document the impact on the well-being of the fish. The initial membranes inside the tube have been replaced by a one-piece inner coating which allows for more efficient cleansing and maintenance. This new inner coating also enables the fish to be turned sideways, upside down and back again by adjusting its shape. Through air pressure between the outer tube and the inner coating, the shape will adjust itself depending on the current purposes (*e.g.* vaccination, stunning).

5 CONCLUSIONS

Peter Stette AS and Picker Technologies LLC have achieved vital information as how to further develop the transportation system in light of industry needs and present transportation challenges. Potential applications have been narrowed, thus providing priority areas in the ongoing development process. A key issue to be solved is how to maintain fish welfare when fish are transported alive in a dry environment. If such documentation can be provided, transportation of live fish might be revolutionized within the aquaculture industry. Hygiene effects and maintenance requirements are also topics which the industry is concerned about.

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