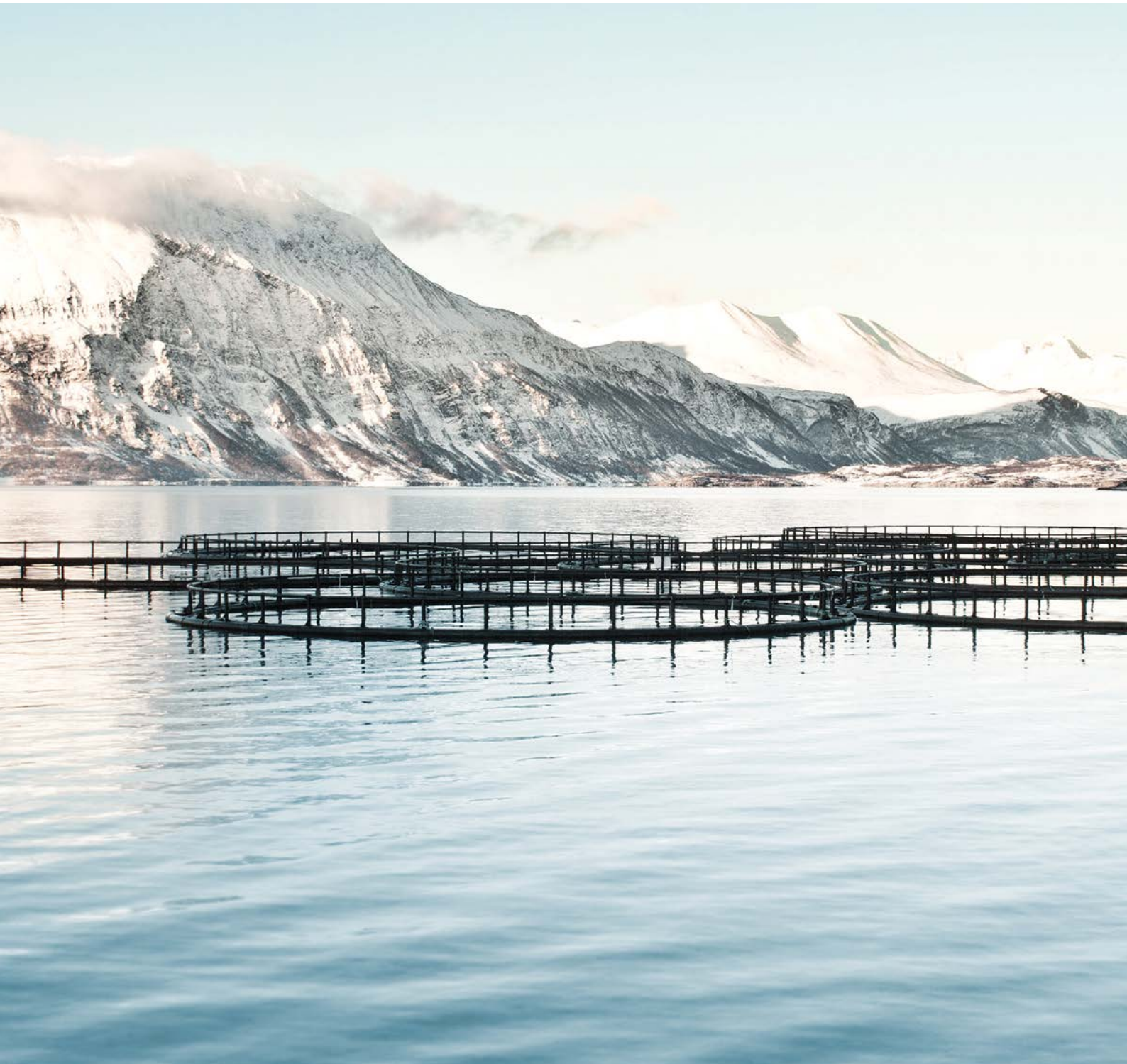
WHITE PAPER

Capitalizing on the boom in aquaculture by harnessing the power of technology and Industry 4.0



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Executive summary

The salmon and trout farming industry has achieved spectacular growth over the last decade. Despite this success, it faces several challenges to continued growth, such as high operational costs and difficult environmental conditions. Using enterprise-wide process automation systems and the emerging Industry 4.0 technologies, companies in this sector could significantly improve their performance as they move towards a future where demand for their products looks set to increase substantially.

1.0 Challenges ahead for the salmon and trout farming industry

While progress in aquaculture has been spectacular during the last decade, this development has been in the making for the last 30 years, led by Norway which now accounts for roughly 60 percent of the market.

Norwegian salmon and trout farming started out as a cottage industry in the 1970s to supplement incomes in rural communities. Gradually, the industry grew in economic importance and, during the 1990s, it consolidated into a number of major national companies. And, according to EY's "Norwegian Aquaculture Analysis 2016" total revenue in this sector grew more than 200% since 2006.

Now, the industry faces the next stage of its progress, as well as a major challenge – how to become a global industry with world-class levels of productivity, service and product safety while dealing with rising operating costs, mainly driven by sea lice and disease.

The Food and Agriculture Organization of the United Nations (FAO) forecasts that worldwide consumption of fish will increase five-fold by 2050. Norway's annual aquaculture production of Atlantic salmon and trout is about 1.3 million metric tons, worth some €3.6 billion. If this were to increase in line with the FAO's expectations, aquaculture may eventually rival the country's oil industry in size.

Increasing the size of the sector substantially will require a significant leap in technology. A great productivity boost, using automation of the type seen in mainstream process industries, is needed if capacity is to increase several times over. Further productivity improvements, in excess of what is available today, will become possible over the coming years as new technologies are introduced.

Many sites today have a high degree of mechanization, with some large processing plants able to process more than 1,000 metric tons of product per day. But there is significant room for improvement.

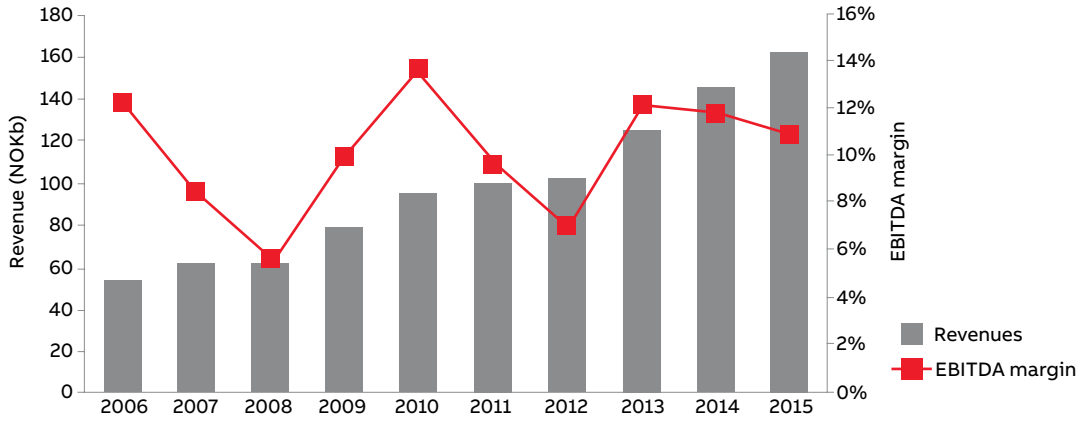


Figure 1. Norwegian aquaculture industry. Aggregated revenues 2006-2015. Source: EY Norwegian Aquaculture Analysis 2016©

Process automation and Industry 4.0
While automation is used on an equipment level in the value chain, the greater benefits of automation have not yet been realized. In general, companies in the food and beverage industry tend to be less automated than other industries, such as electronics or automotive. This is a significant drawback, at a time when digitization is moving at a rapid pace. Companies that fail to keep up stand the risk of losing out to more agile competitors that take advantage of the opportunities the new technology offers.

A number of technologies that have sprung from the growth of the Internet are now making their way into industrial applications. Collectively known as Industry 4.0, these include the Internet of Things (IoT), cloud computing, big data, cyber security and sensors, as well as automation software, simulation and robots. Internet traffic is growing at 23% per year, with the majority of the increase originated by non-PC devices. With cloud storage offerings from several major providers, storing massive amounts of data has become affordable. In industrial applications, this will allow more extensive analysis of product and system behavior than ever before.

These changes will affect all business sectors. As the technology develops, new business opportunities will emerge.

Already, it is possible to build a virtual process line to use for design and test before actual set-up. During operation, the virtual process can be used to predict and optimize performance and to integrate processes across the value chain.

Optimizing the process
With automation, in combination with the new technologies, processes can be integrated vertically through the whole organization, from the production of feed to the saleable salmon or trout product. All data about processes, efficiency, quality and operations planning are available in real time in an integrated network. Key performance indicators (KPIs) are collected at every stage to improve performance. Horizontal integration can extend to partners in the distribution chain, with tracking, tracing, planning and execution. This integrates equipment, people, control and business systems, and synchronizes production processes and logistics operations, while offering plant wide transparency and full traceability.

This level of control leads to improved plant utilization, better food safety, healthier and faster-growing fish and more efficient use of the feed. Productivity can be improved by a few percentage points at every stage of the process. Put together, such gains add up to significant improvement to productivity and to bottom-line results.

Looking at individual processes, a process automation system could:
- Maintain close control of water quality in the fresh water stage
- Provide safe and healthy feed for the fish
- Help keep the fish safe and healthy in the pens
- Assist in transporting the fish efficiently, safely and economically from the pens to the processing plant
- Provide efficient, hygienic processing
- Ensure food safety standards in processing, packaging and distribution are met

By controlling all relevant parameters in every stage of the process and following up on KPIs, the complex process of farming salmon and trout can be optimized. Each stage works towards providing the best value for the process as a whole.

2.0 Background

While the precise growth in aquaculture varies by source (depending on a range of factors including species covered), they all agree that farmed fish is outpacing wild fish for human consumption. For example, in Figure 2 the FAO reported that aquaculture output worldwide grew from about 10 million metric tons per year in 1990 to about 175 million metric tons 2010. In the meanwhile, catches of wild fish remained fairly static during the same period, at around 90 million metric tons per year globally.

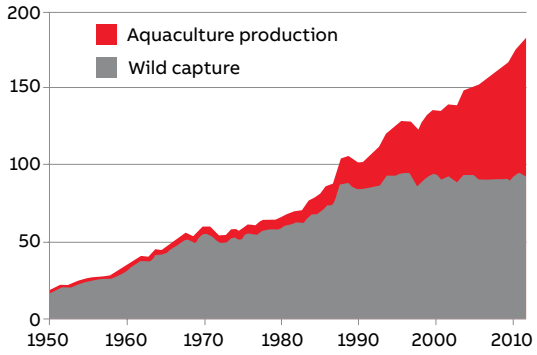


Figure 2. Global harvest of aquatic organisms in million tonnes, 1950-2010, as reported by the FAO.

Marine Harvest's "Salmon Farming Industry Handbook 2017" also shows a high growth trend which is expected to continue for the foreseeable future.

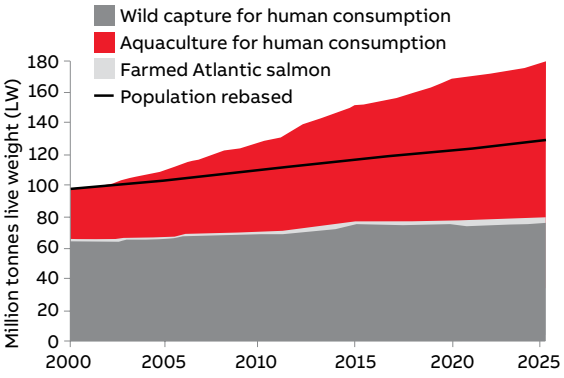


Figure 3. Source: Marine Harvest Salmon Farming Industry Handbook 2017©

Due to a number of biological and geographical factors, salmon farming can only take place in a few places around the world. The map in figure 4 shows the main areas.

Today, only 2% of the human diet comes from seafood, but in some areas it is as high as 70%, indicating that overall consumption could be significantly increased to support growing populations. Agricultural production is nearing capacity and stocks of wild fish are under severe pressure from overfishing, so fish farming looks set to become increasingly important over the coming years. Capture of wild fish can only meet two-thirds of the current demand for fish, so any future increase in demand due to population growth will have to be met by aquaculture.

Fish farming started in China thousands of years ago. It still continues all over the world in its original form, in ponds with herbivore or omnivore species without any particular requirements regarding their surroundings or the quality of the water. The farming of salmonoid species is a much more recent and far more complex practice. Salmon and trout have very exacting requirements and farming them needs significant investment, but the finished product is a more sought-after food product than traditionally grown species and commands a higher price.

Over time, the industry has developed an effective system for rearing salmon and trout for maximum yield, providing a high-quality, fresh product all year round –something which is not possible with wild fish. The methods and technologies developed are now ready to be further advanced with modern automation technology, enabling the industry to take the next step in its development and provide more value.

The process for breeding trout is the same as for breeding salmon. Salmon accounts for about 98% of the industry, so what is said in the following about salmon applies equally to trout.

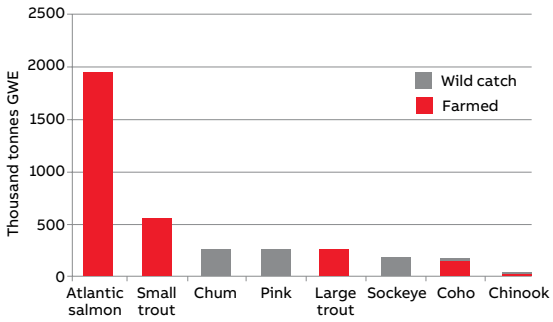


Figure 5. Source: Marine Harvest Salmon Farming Industry Handbook 2017©

Figure 4. Source: Marine Harvest Salmon Farming Industry Handbook 2017©

3.0 Operational challenges in aquaculture – and how to tackle them

The industry faces a number of operational challenges, mainly related to maintaining the quality of the product, controlling the cost and the composition of feed, and controlling the costs related to the production at sea. These issues can all be addressed with the help of process automation and optimization.

The fish value chain
Aquaculture involves a string of processes, some of which run in parallel. Fish farms need to run the process from feed to a saleable salmon product as efficiently as possible. The fish value chain runs from feed production to smoltification, sea farming, slaughtering and processing, distribution and sales. By controlling the whole process, companies can draw benefit from each stage in the value chain. A process automation system can help keep all these stages together and trace products throughout. The objective is to convert feed into saleable salmon product in the most efficient way possible.

Feed production

When a farmed salmon reaches maturity at 2.5 years of age, it weighs about 5.5 kg. At this point, it will have consumed 6 kg of feed, i.e. a conversion rate of 1.1 kg of feed for every kg of product. Compared to other types of meat, this is very efficient; the corresponding figure for chicken is 2.3 and for beef, between 4 and 10.

Industry drivers
The production of feed is a key process to the industry, as the cost for feed can make up as much as 50% of the costs of the whole operation. With high-quality feed, the fish grow faster, but high-quality feed also costs more, so the benefits need to be weighed up carefully.

Environmental sustainability is another aspect when considering the feed. Sustainability is of vital importance to the long-term interests of companies in this industry and this must be considered in all parts of the operation.

Fish meal and fish oil are considered the best quality ingredients for feed. Some of this comes from by-products in the fish processing industry, but a significant part comes from wild fish, typically species not normally used for human consumption, such as blue whiting, capelin and sprat. Even if these are not eaten by humans, other fish species depend on them, so the industry is looking for alternative catches. One such option is krill, a small shrimp that is plentiful in the North Atlantic and is lower down the food chain than, for instance, sprat.

However, if the size of the industry is to increase fivefold over the next 30 years, as predictions show, sourcing feed from wild fish will not be sustainable over the long term.

Alternatives are being sought. Since the 1990s, the share of fish meal and fish oil in the feed has been reduced from about 90% to nearer 30%. The difference has been made up with vegetable ingredients, mainly soy. However, only 3% of the world's soy is sustainably grown.

Another alternative source is abattoir waste. The industry is also experimenting with the inclusion of insect larvae, such as mealworms and black soldier flies, into the fish feed. These can be bred with the use of household food waste, a plentiful resource.

Feed can contain up to 100 different ingredients. Fish are fed different compositions of feed depending on age, weight and health status.

Enabler
A process automation system can ensure the composition of the feed is closely controlled. All ingredients in each batch can be traced through every silo, tank and feed hose it passes on the way to the fish. This way, any problem with the feed can be traced back to its source. The process automation system can be extended onto the feed boats to monitor the loading and feeding processes.

Potential
The cost of feed makes up half of the operational costs and is a crucial element to improving profitability. A process automation

system can ensure that the feed is used in the most economical way.

The composition of the feed has an impact on costs, fish growth and on the environment. The fish need different composition of feed at different stages of their lives. A process automation system helps operators produce the mix they aim for, exactly and efficiently, on every occasion. Changes to the diet can be followed up and monitored, maximizing growth and yield.

Impact of Industry 4.0
A process automation system can provide statistical production analysis tools to help ensure better feed conversion and survival. The volume of feed used up at each location can be recorded and the data transferred to a central location, giving complete control over feed usage. This will show exactly how much feed and which type of feed was used at which time and in which location. This can be compared to the growth of the fish and the feeding regime can be evaluated for future improvement.

Different approaches to automation

Automation helps perform operations that are continuous and repetitive, eliminating manual operations that would otherwise be required. Automation of a production process leads to high yields, uniform quality and high plant utilization with minimized energy losses and environmental impact.

Three types of automation
There are, generally, three types of automation: Supervisory control and data acquisition (SCADA): encompasses network automation for applications needing robust, long-range communication but not necessarily high speed and computing power.

Programmable logic controller (PLC): deployed for factory automation applications with high speed requirements and many discrete incoming and outgoing (I/O) communication channels.

Distributed control system (DCS): used in process automation applications requiring high computing power. There are two variants of DCS, essential automation and extended automation.

Essential automation is scalable and easy to use, providing automation for small- and medium-sized operations.

Extended automation is for customers who want to go beyond the classical scope of a DCS, involving a rich context of information whereby telecommunications, video and/or the power supply side of a plant is integrated along with automating the process.

Three classes of equipment
Automation is based on three classes of field equipment. The measurement products are the eyes and ears of the operation. The actuation products, such as motors and drives, are the muscles that get something done in the field. The control systems, finally, are the brain and nervous system of the plant.

Three process control levels
Automation can be subdivided into three levels aimed at different levels of the company. Level 1 is the traditional instrumentation level with PLC systems and controllers as well as complete process controllers. Level 2 comprises plant control of sub-processes for optimization of yields, often using advanced sensors or automatic analyzers directly in the process. Level 3 includes systems for production coordination across whole plants to minimize costs and maximize yields and quality control. Typically these are managed via manufacturing execution systems (MES) which analyze and control various elements of the production process (e.g, staff, inputs, equipment) in real-time to help decision-makers understand how existing conditions in a given plant can be optimized to improve output. Enterprise resource planning (ERP) systems take this to the next level by allowing companies to manage similar variables across multiple, geographically dispersed production sites while also automating many back office functions.

Industry 4.0
Industry 4.0 is the collective name for technologies that have emerged from the development of the Internet and that are now being implemented to enhance industrial automation. This includes, for instance, cloud computing and big data, two technologies that make it possible to gather massive amounts of data for process optimization.

Smoltification

The life of a farmed salmon starts in fresh water, just like a salmon in the wild, but under controlled indoor conditions. Eggs are mixed with milt and fertilized. The eggs hatch in four to seven weeks, depending on region and habitat. Newly hatched fry live off the yolk sac, which is consumed after about two weeks. The fry then start eating plankton and are also large enough to start eating dry feed.

After about a year, the young salmon is 10 cm long. At this development stage, it is called smolt. It will have undergone a process known as smoltification, which involves a series of physiological changes to prepare it for life in salt water. In the wild, this process can take up to four years but, with the ideal conditions offered indoors, it can be accelerated considerably.

Industry drivers
Inadequate water quality and high temperature in the freshwater stage can result in loss of yield later on in the salmon's life.

Enabler
A process automation system can facilitate water quality analysis, ensuring maximum yield throughout the production by making suitable, timely adjustments.

Potential
Gathering a sufficient number of data points can help an operator learn how various small changes at this crucial stage impacts on the development of the fish later on. Combining several data sources could, over time, help improve the growth and health of the fish.

Impact of Industry 4.0
Cloud computing and big data are two technologies that will enable the collection of very large amounts of data for process optimization as the industry develops and matures.

Sea farming

The smolt are transferred to pens or cages at sea where they live until they are slaughtered. A pen holds up to 200,000 fish. A site typically has 10 to 12 pens, or more than 2 million fish in total.

Controlling parasites is a critical supporting process to the sea farming. Because of the close proximity of fish inside the pen, it is easier for parasites to live there relative to being in the open ocean. The most prevalent parasite is the sea louse. Sea lice drift in from the ocean but, once established, can spread rapidly inside the pen. Early intervention is crucial to stem the outbreak. Fish can be treated with medication or by rinsing in fresh water.

Industry drivers
By monitoring every stage of the operation, a process automation system can help minimize the time it takes for the salmon to reach maturity. Everything that happens to the fish is recorded, from breeding in freshwater, to seawater quality, feeding and medical treatment. This can be compared to gains in biomass and evaluated for process improvement purposes.

Fish stocks can be decimated by fluctuating seawater temperatures, low oxygen levels, plankton and many other environmental factors. A process automation system can keep a close watch on oxygen levels, temperature and various other parameters. By collecting data and making adjustments over time, an operator can optimize the combination of feed type, temperature, oxygen levels, etc, to maximize growth and yield.

When a parasite infestation has been brought under control, the number of parasites can be kept low with the use of cleaner fish. These are fish species which, in nature, have developed a complex behavior where they help relieve larger fish of parasites. The larger fish will tolerate the close presence of the cleaner fish and will refrain from eating them in return for being cleaned of parasites. Cleaner fish are bred indoors, in an operation parallel to the salmon breeding program. The process automation system can also help ensure that the breeding of cleaner fish is as efficient as the breeding of salmon.

Any oil products that float into the farm will harm or kill the fish and may leave an unpleasant taste on the meat of any surviving fish. Instrumentation in and around the farm can monitor water quality continuously and alert staff about changes.

Enabler
All visual monitoring at the sites can be automated using, for instance, cameras under water and above the surface. Oxygen levels can be monitored, using online oxygen measuring equipment, alerting the staff when changes occur.

Electric propulsion can be used for the feed boats. Electrification is affecting large parts of the transport sector at the moment. Electric propulsion, in combination with batteries, has

many advantages such as enhanced efficiency, lower emissions and improved redundancy. For marine applications using vessels that only do short trips, such as those used in the salmon farming industry, plug-in electric battery hybrid propulsion is ideal when they use clean grid power.

Potential
Using hybrid electric propulsion, boats can operate with higher safety and efficiency. Battery power is more responsive to sudden load changes caused by swells and wind squalls, for instance. This reduces the risk of the engine stalling, causing loss of control and jeopardizing safety. If the main engine should fail, for whatever reason, the vessel can operate on battery power until an auxiliary engine can be started.

Vision cameras can identify individual fish. Occasionally, very detailed tracing may be required that goes beyond tracking the fish back to the pen it came from. For instance, if fish are moved, it can be difficult to know where they came from originally. Using vision cameras, individual fish can be identified using the pattern of the scales, which is as individual as fingerprints on humans.

A process automation system can help minimize salmon escaping by monitoring the nets continuously for wear and weakness using cameras below and above the water surface. Additionally, any farmed salmon found in the wild can be traced back to where it came from.

Underwater cameras can keep a lookout for attacks by animals such as seals. An alarm system can be used under water to deter the animals with sounds. Similarly, birds on the surface that prey on jumping salmon can also be deterred by an alarm.

The behavior of the salmon inside the pen can be documented using cameras above and below the water surface and the footage can be used to look for abnormal behavior which may indicate presence of parasites. The automation system can also help monitor the use of medication.

Feeding can be completely automated. Today, most sites are manned, with one person at each site feeding the fish. Some operators perform this task better than others, resulting in different growth rates at different sites. Feeding can be centralized and optimized, ensuring best practice is applied at all sites so that feed availability is equal and the feed is used efficiently. This is achieved by monitoring the rate of delivery and controlling the pressure in every feed hose.

Impact of Industry 4.0
Cloud computing will enable the storage of very large amounts of data, helping operators keep data about individual fish and every single feeding session.

On-shore farming

Some fish farms are based on land. Known as recirculating aquaculture systems (RAS), these benefit equally from automation.

Industry drivers
Compared to sites at sea, RAS sites tend to be small but have undergone significant development in the last decade. Ten years ago, an average site was 5 meters (m) deep and 10-15 m across. Today, they are typically 30 m deep and 50 m across. These installations are often used for keeping smolt but can also be used for fully grown fish.

These systems can be fed by a pumped water supply, or a natural water stream. Either way, the water supply will be limited and the operator will need to control water usage.

Enabler
An automation provider can supply pumps, motors, drives, electrical cabinets and analyzing systems, all controlled by a process automation system. The system is optimized to ensure water and electricity are used economically. The operator can keep close check on the water quality using a spectrometer, making results of water quality tests immediately available. This eliminates the delay that is caused when water samples have to be collected and sent to a lab.

Potential
RAS systems can be based near an existing sea farming operation to complement the existing process. But they can also be based in an entirely different places. In the future, it may be possible to export complete RAS systems to locations closer to the markets.

Impact of Industry 4.0
Expert systems and artificial intelligence may make it possible to capture the know-how needed to run a salmon farming operation, using a RAS system, in a new market with local staff.

Slaughtering

When it reaches maturity, the fish is collected with a special type of ship known as a well boat. The living fish is transferred to an onshore plant where it is anesthetized, bled and gutted by machine.

Industry drivers
The management and handling of the well boats is a costly and potentially hazardous part of the operation. As well as moving fish from the pens to the processing plant, the well boats are also used to temporarily hold the fish, for instance during medical treatment.

Enabler
Just like the feed boats, the well boats can benefit from hybrid electric propulsion for safe and efficient operation. The automation system can be extended onto the well boats.

Potential
The automation system can provide traceability of where fish have been held and data on any medical interventions which may have been required, along with information on responsiveness to treatment which could inform future decisions.

Impact of Industry 4.0
Large volumes of data can be stored and used to trace each fish through the process and document every place it has been held.

Processing, distribution and sales

Using automation, each stage of the process can be optimized to ensure it operates with the minimum input of time, effort and energy, from breeding and farming through to processing, distribution and sales.

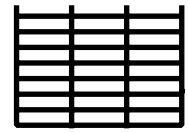
Industry drivers
Traceability is vitally important to ensure food safety, as it enables the company to go back as far as necessary to find the root cause of any problem. Traceability can also be used proactively to find the root cause of issues that need resolving in order to improve the process going forward.

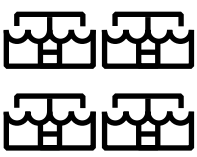
Companies in the industry often rely on a small number of key staff, often based in remote areas. With standardized equipment across the company, staff will be able to transfer between sites with little training, making the operation more flexible.

By quantifying every stage, operations managers will also know, at any given time, exactly how close the plant is to meeting its production target for the day.

Enabler
A process control system will help with collecting well-defined KPIs to closely monitor quality through the production chain. KPIs can include parameters such as machine downtime and production rate.

10-16 months





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Spawning and smoltification

- A process automation system can provide statistical production analysis tools to help ensure better feed conversion and survival
- Analysis of volume, type and timing of feed across locations can be compared to fish growth allowing the feeding regime to be optimized over time
- The impact of other factors such as water quality and temperature can also be reviewed and controlled more effectively to improve the growth and health of the fish

With a process automation system, each fish can be identified and traced back to the tank where it was bred.

The automation system can monitor the power supply to ensure processes can operate uninterrupted.

Potential
With an enterprise resource planning system integrating what would have previously been silos of information, throughput time can be halved. This reduces the total cost of ownership for plant assets. Product quality improves as the operator has access to more information. Food safety is also enhanced given better scope to trace the product from beginning to end.

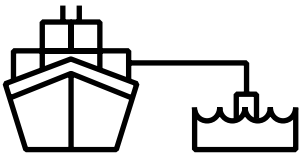
A manufacturing execution system acts as an intermediary layer between the enterprise resource planning system and the automation system, tracking and documenting the transformation of raw materials into finished goods. This helps to eliminate waste, maximize flow, empower operators, create ergonomic work places, ensures operations are right first time, and minimizes inventory. Production can be adjusted to real-time demand and robotics used for flexible production.

Impact of Industry 4.0
The boundaries of what can be automated are shifting and new application areas continue to emerge. Robots help improve quality by reducing the risk for error. They also reduce risk by keeping workers away from moving machinery and relieve workers of repetitive tasks that could lead to strain injury. Humans and robots may collaborate by each doing one half of an operation. Robots also improve food safety as the product can move through the process without being touched by a human hand.

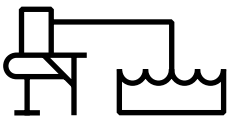
A cloud service can be used to securely collect and analyze motor data. Sensors on motors at the plant collect data that is uploaded and viewed by the customer or the equipment manufacturer, or both. An operator can have transparency at his fingertips, seeing all that goes on throughout the electrification and automation plant. Remote monitoring services enable proactive maintenance.

Tracing can be extended beyond the confines of the company and into the distribution chain.

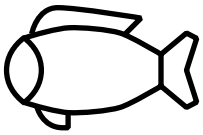
14-24 months



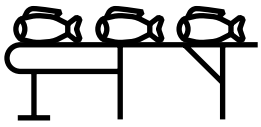
Transfer to/from sea pens
- Hybrid electric propulsion can be used for safer, more efficient transfer of smolt to cages at sea, as well as for delivering feed.



Growth (onshore or at sea)
- Process automation can minimize the time it takes for fish to reach maturity by matching factors over time to growth patterns.
- Fish yield can be maximized by keeping a close watch on environmental factors, parasites, escaping fish, predator activity etc.
- Feeding can be completely automated as can medication delivery.



Slaughtering
- Large volumes of data can be stored and used to trace each fish through the process and document every place it has been held.
- Food safety is also enhanced given better scope to trace the product from beginning to end.



Processing and sales
- With an enterprise resource planning system integrating what would have previously been silos of information, throughput time can be halved, reducing the total cost of ownership.
- Production can be adjusted to real-time demand and robotics used for flexible production.

4.0 Process automation meets the industry's challenges

In a process automation system, all operations can be closely monitored and controlled across the feed plant, smolt plant, cleaner fish plant, fish farms and the processing plant. All information is brought together to one central location. Every batch of product and every individual fish can be traced, even those still at sea in the pens.

Operations that are located away from the main plant can be fitted with scalable systems and integrated with the main operation via a remote connection, enabling operations managers to see the whole picture, regardless of where they are.

In other industries, productivity improvements of up to 20% have been achieved through improved operator visibility of entire plant assets.

Process automation can be installed as a turnkey solution together with high voltage equipment, switchgear, cabinets, distribution boards, motor control centers, drives, instrumentation and motors, all backed up by a 24/7 service and spares and perhaps also operational support.

By integrating process automation and electrical equipment, further advances can be made in productivity, safety and cost reduction. This way, a complex system can be maintained by a small number of staff.

Performance indicators are clearly shown by the process automation system. The new Industry 4.0 technologies make data collection easier than ever. Instead of basing decisions on volts and amps, staff can make their judgments based on parameters that add value to the operation. The interface offers operators quick and effective ways to analyze and troubleshoot routine as well as abnormal conditions.

A process automation system provides a unified, collaborative environment where decision-making can take place in real time, increasing operator effectiveness and improving production performance.

It offers a visual environment for easy design and deployment of automation strategies, process visualization displays, information management, asset optimization, and field device integration. With a flexible, distributed engineering environment, data can be accessed, created and modified simultaneously by different users.

Knowledge management software is used to collect, store, retrieve and present current and historical data for KPIs.

Asset optimization software uses databases with plant information to monitor, assess and report equipment conditions in real time to reduce costly maintenance.

The system connects enterprise and plant systems, applications and devices. This simplifies operations, engineering, control and maintenance.

With process automation, the salmon and trout farming industry can meet its challenges and move on towards its next phase of expansion.

Challenge	Issues	Benefits of technology
Quality	Collecting performance indicators	Indicators collected automatically
Feed costs	Reduce overall costs	Feed used the most economical and efficient way
Feed composition	Complex feeding regime	Provide the right mix at all times
Maximize yield	Manual feeding results in different growth rate at different sites	Feeding can be centralized and optimized
Production time at sea	High production costs	Process is optimized to reduce production time
Boat safety and economy	High costs. Engine stall when loading	Hybrid electric propulsion more economical and less prone to stalling
Environmental conditions	Fish affected by water quality, pollutants, etc.	Real-time monitoring of water quality
Escapes	Worn equipment gives fish opportunity to escape	Fixed cameras monitor equipment for wear
Predation	Seals try to penetrate pen underwater	Alarm system to deter animals with sound
Freshwater quality	Water quality affects yield later on	Automation system keeps close check on water quality
Personnel	Reliance on a small number of staff	Automation reduces reliance on human operators while standardized equipment enables staff to move easily between sites

5.0 Conclusion

The top priorities in the salmon farming industry are to maintain quality and safety throughout the production process. Every stage in the chain, from the feed factory to the saleable salmon product, needs to be as efficient as possible to achieve this goal.

To that end, the industry needs to offer the best possible conditions in the fresh water stage; provide safe and healthy feed for the growing salmon; keep the salmon safe and healthy while growing in the pens; offer safe, efficient and economical transport of the fish from the pens to the processing plant; provide efficient and hygienic processing; and maintain food safety standards throughout the processing, packaging and distribution chain.

With an enterprise-wide process automation system, companies in the salmon and trout farming industry can achieve this. By controlling all relevant parameters in the process, and following up the KPIs, the complex process of farming trout and salmon can be optimized to ensure each stage works towards providing the best value for the operation as a whole.

A process automation system will integrate operations and standardize equipment across the company, enabling more flexible working practices. It will also help address the specific operational challenges that the industry faces. Finally, it will optimize the production chain and ensure that the process delivers maximum value and profit.

With the benefits of process automation, the salmon and trout farming industry will be equipped to fulfill its role as a supplier of high quality food products as demand for marine food multiplies in the coming decades.

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