Climate Change, Industry Change, Weather and Risk in Marine Aquaculture

Report on Canada-Norway Dialogue # 3, March 18th 2024

Charlie Mather from Memorial/OFI moderated this third Canada-Norway Dialogue. He opened by welcoming everyone and introducing the presenters. The first presenter was Dr. Joel Finnis, atmospheric scientist from the Geography Department at Memorial University of Newfoundland/OFI, followed by Drs Ingunn Holmen and Trine Thorvaldsen from SINTEF. The discussant for Dialogue # 3 was Dr. Tiina Ikäheimo a professor in the area of human performance and health in extreme environments based at the Arctic University, University of Tromso in Norway. The stakeholder lead for this Dialogue session was Claire Brown, Raspberry Point Oysters.

Joel Finnis' presentation was co-authored by Lissandra Cavalli and Josh Brown and entitled **Weather- and Climate-Driven Risk Considerations for Atlantic Aquaculture.**

In opening, Joel commented that his background was in climatology and meteorology but in recent years he has been pulled into more discussions about how weather and climate risk are communicated, how risk messages are interpreted and decisions around that. The focus of the talk was on marine hazards and one industry sector, marine aquaculture. He noted that all marine work is inherently risky. He defines marine weather as any transient shift in marine environmental conditions typically lasting from a few hours to a season and encompassing both the atmosphere and the ocean. This broad definition encompasses anything that would require a message from weather forecasters or action by aquaculture operators.

The variety and character of weather hazards, he notes, differ by industry, region and season and weather impacts on risk will depend on what is being done and related exposures and what kinds of vulnerabilities are built into the operation.

The presentation was organized around three core themes: 1. some of the weather concerns of aquaculture operators; 2. the strategies employed by operators to mitigate weather hazards and 3. The impacts of climate change on hazard exposure and weather preparedness.

When he thinks of the kinds of weather hazards confronting marine aquaculture operations, he tends to compare aquaculture to fisheries in part because the latter is better studied. There you can look at how wind and waves might influence vessel motion and what they might do to infrastructure on the water and onshore. You can also look at issues like icing and how this can potentially damage and destabilize structures, and enhance slipperiness for the personnel. Visibility is another shared potential hazards between fisheries and aquaculture and, as in fisheries, there are also hazards associated with floating sea ice and icebergs which can affect personnel, vessels and other infrastructure.

There are also specific concerns within aquaculture relative to fisheries including the potential impact of weather on the health and quality of fish/shellfish stocks. For example, marine heat waves can drive or contribute to some mass mortality events and or degrading the quality of many shellfish or even put them at risk of mortality, cause build-up of toxins, etc. There is also heavy precipitation and food safety protocols that can shut down areas and leave shellfish stranded and unable to bring to market.

Three key categories of concern include what weather might do to personnel, infrastructure and fish stocks. Different things have different impacts: wind and waves can contribute to personnel risk but pose less of a risk for fish and infrastructure. Moving ice and icing can impact personnel and infrastructure. Heat can affect fish, as can heavy rainfall, but these can also contribute to OHS risk including through exposures to ultraviolet light and heat exposures and, in the case of rain, increases in slipperiness. The strength of connections between hazards and personnel, infrastructure and fish can vary as well.

When preparing to deal with weather-related hazards and having identified what is at risk and the type of risk, there are different techniques you can use but the first line of defense for operators will need to be some kind of climatological analysis. They need to stop and think about what kind of weather they might expect in a particular area before identifying locations, designing infrastructure and set-up. They will normally assess wind, waves, and impacts on work and infrastructure. They might also look at climatological risk, including heat waves. This can help them prepare for the likely extremes they might expect. Even small operations without access to explicit climatological analyses might do some implicitly. For instance, in Atlantic Canada shellfish producers might limit the species they use to those that are native to the area because they know these can survive in local conditions.

Regardless of how much climatological analysis operators carry out, there will always be some weather risk. There are various strategies to mitigate weather hazard risk and one of the first things they can do is keep personnel on shore in the event of bad weather. The period of time during which they can use this strategy will depend on the farm and on whether, for example, they have access to remote feeding systems and other systems for monitoring what is happening on the farm remotely. They can also harvest preemptively if forecasts indicate the onset of a particular event that threatens fish health but it is important to acknowledge that there is a potential conflict between different kinds of solutions. Regular monitoring of weather effects and of fish stocks requires people on the water, as do some event preparations, like fish/shellfish harvest and checking anchors, etc.

Moving systems further from shore can mitigate some weather-related risks, as with threats to infrastructure, but this will require more time to travel back and forth between the farms and the shore and this could pose injury risks during a weather event. So, you can have situations where trying to deal with infrastructure and other threats can come into conflict with personnel safety concerns.

The tools available to inform us of impending weather events are better than they were; there has been a real boom in tools for weather preparedness. We still have the marine forecasts although these use large forecast areas. We also have various ways to view weather model output directly and, this is still something relatively new for website users, tools that visualize weather patterns using models from Europe, US, and make them available as satellite visualization maps showing, for example, what is going on with sea surface temperatures and other things based on remote sensing applications. This is widely available now, but was not available to most users 15-20 years ago.

So, we have more, better monitoring and forecasting capabilities and these are constantly improving. We have 10 plus days of useful information from models, 3 days of highly reliable forecast guidance, 4-7 days reliable, etc.

In terms of climate impacts, if we think of weather as external risk, climate change is a source of manufactured risk, a human created problem that shifts weather considerations and risks and Gerald

referred to another form of manufactured risk that comes along with that- the risk of mass mortality events. The thing about climate change is if an aquaculture system works under current climate conditions in terms of risk mitigation, it might not work as well in the future including for potential new risks that have not occurred before.

A good example here for Atlantic Canada is Hurricane Fiona, a recent, record-breaking storm. This was a complex event, an old hurricane/post tropical storm that underwent a transition into a record-breaking storm for Canada. By many measures Fiona was the strongest storm ever observed in a Canadian territory. Fiona was well-predicted; by the time it made landfall we had been getting steadily amplified risk messaging, so there was plenty of advance warning! And there was some time to consider and implement mitigation options (e.g. rescheduling work). There have been other storms like Fiona recently- think of Dorian. Some organizations responded to Fiona as if it was Dorian. Looking back makes sense, but anything unprecedented can sometimes upset those expectations. We have heard, for example, that some shellfish operations did what they had one in the past but these did not work with Fiona. I am thinking here of sinking oyster cages, unfortunately with Fiona, there was so much runoff that it ended up burying cages in the mud. So, in trying to protect the cages from waves, they ended up exposing them to sediments. If similar events happen in the future, we might have to adjust some of our responses.

Also, with climate change preparation, one of my major concerns is changes in sea surface temperatures across the North Atlantic and with the recent Atlantic Marine Heatwave. With that, we have been experiencing statistically unthinkable warm sea surface temperatures for over a year and we are coming into 2024 with even higher temperatures setting the stage for even further amplification of this marine heatwave over the coming summer. He and an honors student, … looked at sea surface temperatures associated with the salmon mass mortality event that occurred in Fortune Bay in 2019. Based on an examination of heatwaves in that area over the previous 20 years, the one that coincided with the MME in 2019 was statistically insignificant and yet it was still associated with the death of 2.6 million fish. They projected forward using two climate models to look at the relative frequency of very long heat waves into the future and the findings were quite alarming indicating, even with the more cautious model that what used to be an 80-year return event could happen every 2-3 years, a 29-fold increase in risk. The situation is certainly alarming with Fortune Bay expected to be considerably warmer not too far into the future and our models may be under-estimating the speed of change. Based on the current heat wave, these models are too conservative and are under-estimating things like sea ice loss in the Arctic and changes in sea surface temperature in the Atlantic.

In summary, I have presented a broad overview of relevant marine weather and climate change considerations for aquaculture. The exact nature of climate change impacts will vary in other regions as will difficulties with unprecedented/extreme events. Certainly, we need to use caution and anticipate surprises.

Relevant References

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The second presentation, by Ingunn Holmen and Trine Thorvaldsen, was entitled **Holistic Risk Perspectives and New Production Systems.**

They opened by talking about they mean by holistic risk perspectives and why they have adopted this approach. Essentially, holistic risk perspectives look at multiple risk dimensions together and a key reason for this is that, based on their research, the different risk dimensions influence each other. For example, the initiatives taken to reduce risk on one dimension, such as reducing the risk of fish escapes might, as research has shown, increase risk on the health and safety dimension. In addition, they noted, with more extreme weather, there is a growing need for new measures that will safeguard not only farm infrastructure but also fish workers and the environment.

Ingunn then provided a very brief introduction to Norwegian aquaculture for those unable to attend previous sessions. She noted that it involves almost exclusively finfish farming and that Norway is the world's number one producer of farmed salmon and rainbow trout. Already an important contributor to the production of wealth in Norway, the industry is expected to become more important in the future. She reminded participants that although the industry is profitable, there continue to be safety challenges in the industry and concerns about risks to the environment.

Ingunn reviewed the regulatory framework for Norwegian fish farming (see presentation) identifying seven regulatory areas that are applicable to the grow-out phase of fish farming (their area of focus). All Norwegian companies are required to implement safety management systems and risk assessments are mandatory across all 7 areas. They are regulated by five Norwegian authorities which are responsible for these 7 areas: the Directorate of fisheries, the Maritime Authority, the county governor, the Food Safety Authority and the Labour Inspection Agency. They are required to follow up with each of these authorities so the system is quite fragmented. What they have suggested is to look in a more holistic way at risk management and perhaps try to combine the documentation that the companies have to produce to prove they have implemented what they should do in each of the risk areas.

Some years ago, they presented a new holistic risk model for Norwegian fish farming. Because the farms are located at sea and exposed to all kinds of weather including exposure to wind, waves this would also influence the level of risk for fish escapes, parasites, infections, handling, treatment and mortality and

for workers OHS. In terms of the latter risk dimension, the Norwegian aquaculture industry is the second most risk exposed occupation in Norway and this is linked to working on moving platforms, exposed to wind, waves, the use of cranes, etc. The external environment must be protected from pollution and they are very concerned in Norway about threats to wild salmon due to fish escapes. There are also food safety risks related to which it is important to manage the use of chemicals for the treatment of parasites, etc. The last risk dimension is risk to material assets. Fish farms, feed barges and vessels may be damaged by accidents, wear and tear and gales, vessels may collide with fish farm elements, and moorings are a potential issue.

Previous studies have indicated that current aquaculture sites in Norway have already reached safety limits due to extreme conditions, etc. and a lot of developments are ongoing in an effort to address risk. But there are also new and emerging risks to be considered. Joel has already pointed to climate change but first let's talk about the risk of sabotage. They saw earlier this winter in Chile that a lot of fish escaped after sabotage at a Chilean farm after net pens were deliberately damaged by a third party. Third party attacks seek to cause damage, including reputational damage to the industry. Climate change can cause harmful algae blooms as happened in Norway when 1,000s of fish died when they suffocated. Increased water temperature is also a hazard to fish as shown by mass mortality events in 2019 when Mowi Canada East lost half of its fish at a location in NL. This is also a known risk in Scotland. Knowing about this risk can help inform the development of mitigation tools. For instance, they have improved the survival rate of fish on Scottish fish farms by oxygenation of the water because one of the consequences of higher water temperature is reduced oxygen. They also keep fish in the sea for less time and have improved feed monitoring and developed new feeding strategies. They are all examples of ways to mitigate the hazard of increased water temperatures.

In Norway fish farming industry has a reputation problem and they also have challenges that they need to work harder to address. Furthermore, further growth of biomass is coupled to combating the salmon louse and the system for doing that is called the traffic light system. This system was introduced in 2017 and it is based on reports from all of the farms. The authorities monitor lice across multiple regions and each year the minister decides if they will allow an increase in salmon production in that region. In recent years growth in production has stagnated so delousing, etc. is a priority for the companies.

Preventing fish escapes very important to the farms and is very closely connected to reputation. They have heard stories that workers will risk their own safety to prevent escapes and fish escapes also represent economic loss to the companies so they focuse, of course, on preventing fish escapes. They don't want to see their income swim away.

Regulatory requirements also emphasize the need to protect fish welfare and OHS and these can entail conflicting objectives, as mentioned by Joel. In terms of material assets, they are developing new technological concepts to help address the multiple risks in the sector but these can come with new hazards for farmers related to maintenance and repairs and the need for novel skills, etc. So, before these new fish farm concepts are built, risk assessments should be done to try to identify as much as possible risks associated with the future operation of these new fish farms.

Trine then took over the presentation to discuss opportunities and challenges associated with the new production systems that are being developed for salmon aquaculture in Norway. Her part of the presentation draws on two ongoing projects she is managing including one on OHS in aquaculture and one on risk management in new production systems. For one of these studies, they reviewed the farm

concepts in applications submitted for development licenses under a system introduced by the Norwegian government in 2015 to encourage innovation. They did an analysis of the concepts submitted for the development licenses a majority of which are for closed unites but many also were for open net pens with plastic collars including some semi-submersible models. This work was published in Aquaculture Reports.

New areas and new production systems

Land-based systems were not part of the development license policy. It is aimed at sea-based systems but land-based farms and some hybrid farms are part of the diversity in aquaculture production facilities in Norway. Salmon hatcheries have used land-based production systems for decades and while there are only 3 land-based operations in Norway producing salmon up to 5 kilos, there are 31 land-based projects under development. There are also some hybrid systems.

In sea-based production, escapes and salmon lice are huge issues and some solutions involve utilizing new areas in fjords including areas more exposed to wind, waves, currents and even offshore areas. Weather-related risk will be a major factor confronting several of these new sea-based systems, more so than land-based systems. There are OHS hazards in land-based systems, but they are different from working at sea. Those risks include washing tanks, chemical use, etc.

The companies that are developing the new farm concepts are very concerned with handling OHS challenges in a systematic manner and thinking about the workers in all stages of production. Based on a review of the development proposals, some are for closed containment sea cages that have impermeable barriers separating external areas from internal ones housing the fish. They usually have purification systems and these sea cages will respond quite differently to environmental conditions from the current types of sea cages due to increased drag forces and also the potential problem of sloshing inside of the closed cage. In 2021, there were about 20 companies in Norway developing these kinds of systems; several had been developing them before the development license program was announced. They are designed to protect fish from lice and could lead to a more predictable production cycle but diving operations must be performed and the same is also true for so-called submersible systems that entail lowering the cage to below the strata associated with lice production. If these systems become more common, they will require more specialized divers which is very important from an OHS perspective. Alternatively, they will need more advanced ROVs.

In the case of systems designed for offshore aquaculture, in the literature this is referred to as open-ocean aquaculture (there is still not a clear or agreed upon definition for offshore but the term is usually used to describe sites several kilometers from the shore. These systems lack shelter from the elements and thus are more exposed to currents, winds, waves and swell. They are commonly open-net pends but they will need more robust systems. They are not yet established in Norway and they regulatory frameworks are in the design phase and several companies want to do this. As mentioned the last time, emergency preparedness will be very important for these farms. The construction is very different from the existing systems and they will each contain a lot more fish.

There are similar challenges and opportunities between the production systems. The challenges include the need for energy infrastructure as all new systems will require more energy supplies than traditional net pens and for all of these systems there are potential conflicts with other stakeholders (on land and at sea). They may introduce new OHS risks but you if look at the opportunities, they may reduce OHS

risks for workers because of more predictable production, without sea lice and the new technology may help to increase the growth of the industry without harming of the marine environment. There should be less release of waste as many will collect the waste from the systems.

One issue is interactions between contractors and fish farming companies. This is not a challenge solely related to the new production systems. Outsourcing of production may affect OHS, this is well-known from other industries. They did a survey with about 300 respondents who worked for contractors and they expressed concerns about this: 66% think lack of cooperation with fish farming companies is a threat to safety; 56% said fish farming companies' demands for efficiency mean that they sometimes have to break safety procedures; and 55% agreed they felt the work they do is undervalued by the fish farming companies. This links back to the issue of the need for holistic risk assessments and this is something they are looking at now. New production systems aim to solve problems with lice and the environment but OHS risk can be affected.

Discussant Tiina Ikäheimo from the University of Tromsø thanked the organizers for the opportunity to speak on the topics and the presentations. She noted her knowledge of aquaculture per se is limited so her comments will focus more on the overall impacts of changes in climate and how an industry, like aquaculture, can adapt to these changes and their implications for OHS. As a result of climate change, both Atlantic Canada and Norway are seeing increased temperatures, more frequent heat waves, longer periods of higher temperatures, a reduction sea ice with related impacts on precipitation, storm tracks. We can expect an increase and increased intensity in snow and rain and more solar radiation, and due to temperature increases and loss of ice, an increased risk of erosion, storm surges, flooding. Climate change is bringing more frequent extreme events and higher temperatures; weather more changeable and unpredictable. When we look at climate change from the point of personnel, infrastructures, fish and shellfish health, it is likely the vulnerabilities of the industry to weather vary by region and the type of operation in question. When we consider that from an occupational health point of view, aquaculture is the second most risk-exposed work environment in Norway and one in which foul weather plays an important role, it is important to be aware that high and low temperatures affect cognitive performance and this affects injury risk. More heat and UV exposures also have health effects. With cold weather you get the risk of cold injuries on bare skin and this risk can increase if skin is wet and with high winds. The infrastructures on board vessels and aquaculture sites can also affect injury risk through increased risk of slips, falls; visibility reduction can enhance risk. Storms and heavy rainfall can damage infrastructures and lead to fish escapes and with high precipitation risk and extreme weather, the logistics of transport change need to be considered. The changing environment can affect the health and quality seafood directly and indirectly. Higher temperatures and reduced oxygen can indirectly affect the spread of pathogens and diseases, resulting in increased mortality rates and reduced productivity. Weather and temperature also affect the overall growth rates aquacultured seafood and increased CO2 can affect shell formation.

What are some ways to adapt? We need short and longer-term action plans for decision-making including in relation to OHS. We also need to keep in mind vulnerable workplaces, job tasks and vulnerable populations of workers – these need to be treated separately to ensure they are not negatively affected by interventions in other parts of the system or with other groups. We need to think about the most suitable places for practicing aquaculture while taking into account current climate conditions and the long-term effects of weather and the characteristics of the species. We also need to invest in sustainable infrastructures. The recent technological innovations presented by Trine can have

both positive and negative impacts. The automation of feeding, for example, can protect personnel from foul weather but, as argued by Ingunn, companies should adopt a holistic risk management framework that include checklists for the different hazards and observed hazards need targeted measures to reduce risk. We also need proper education of personnel, including OHS personnel. Risk communication should be integrated as permanent practice in everyday operations where new employees need special attention and, she indicated, she can't over-emphasize the role of workplace leadership. Company managers should commit to priorities that value well-being over profits. We need to develop systems that enable rapid responses. Forecasts allow for decisions to be made around when it is safe to send out personnel and can inform short-term adjustments for the fish but as indicated by Joel, despite these, there can be surprises. Short-term responses for protection of personnel need to consider work-rest scheduling, decisions around delayed feeding, and when to administer medication to fish. In the case of weather hazards, personnel also need to think about what kind of personal protective equipment will be needed for particular situations. Aquaculture is facing new challenges due to changing climate and weather changes and these are some questions to think about: 1) to what extent do companies think about operations in a holistic way? 2) Are companies considering the changing climate in their decision-making? 3) What kind of supports are needed to make this happen?

Claire Brown from Raspberry Point Oysters played the role of stakeholder commentator in setting up the wider discussion. She indicated that Raspberry Point deals with oysters; they process about 25 million oysters a year through a farm and relay system. Her job is to evaluate risks and to go back to Fiona, in total Fiona cost PEI aquaculture about $70 million dollars. They lost some oysters and cages and there were extra costs for manpower. A key problem with Fiona was a lot of debris from an island north of the Raspberry Point had a lot of rotten trees and, with Fiona, these came through their leases. This caused a lot of their problems. There was a lot of mud as already mentioned Joel and that filled up the trays and killed the oysters. They had over 40% mortality on that side of things. With Fiona it was a combination of wave energy and directional winds. These were areas where they had not really focused in the past and as a result they have now changed the angle of their cages in some areas. They are considering, a lot more, wind direction. They are also implementing weather systems at each of their sites and have had to add more lines to their cages. These are some of the important things they are doing. They are also working with watershed groups because due to coastal erosion, wave action can be sharper. In one area they are trying to improve the tree cover and change the gradient. Because of the storm surge issue, they have raised all of their buildings to reduce risk of flooding. There is also concern about contamination of wells. At moment they are trying to set up depuration facility that is mobile and one reason for this is storm surges that, coupled with temperature increase can lead to an increase in pathogens. With more phytoplankton there is more potential DSP coming through so they are working on an inland system to help with depuration of their oysters and to get more understanding of how the pathogens are working. In Massachusetts, an entire depuration system shut down to a storm surge and they have a new disease- a type of leukemia- that they think is due to temperature increase.

In the case of climate change we are dealing with increased energy and waterway runoff and changed the setup of their cages. They used to put oysters at the bottom of cage but that can be turned into a mudpie after storms so now they are leaving the bottom empty. As a result of this change, they have seen a huge reduction in mortality from 16% to 4%. They are seeing a lot less ice coverage and that is a double-edged sword. The change of ice coverage is double-edged sword because it can allow earlier harvesting, but ice can also act as a buffer against wave energy. Currently we are finding it is not quite thick enough to walk on, but too thick for our boats to pass through safely.

In terms of climate change and changes in the Ph of the water, a lot have mentioned the risk to shells of a decrease in Ph but our bays appear to be trending upward instead, although there are still a lot of data to work through. She is not sure why. If there is more acidification they could get thinner shells and the oysters might spawn faster. That sounds good but weaker shells will reduce the grade in markets from premium. They are trying to figure out the relationship between tunicate and increased temperature. DFO says the tunicate population could double and that will increase the need to flip the cages to dry them out. If the water is warmer they will need to work more in the evening when it is not so hot. The guy might have to move to more of a 24/7 schedule and that will add to costs. Environment Canada is expecting a 20% increase in precipitation and that will mean more run-off and potential anoxic events for them. They need the community for their business but that can increase the risk of runoff. One last piece: they have been working on 5 years of data from 6 agencies related to water quality. In the last two years they have been measuring for e coli, vibrio and salmonella. If there is an extreme weather event there will be increased risk from these contaminants. So what she would like to see from researchers around the world is more collaboration. We have to ensure research doesn't sit in a fancy spreadsheet. Realistically, what does climate change mean for specific species and how is it different for aquaculture in bays versus in open waters? They have implemented an online tracker for a farm called Ocean Farmer. They are trying to get their greenhouse gas emissions down. It is important to look at climate change but you can also reduce your own impact as a company and become more efficient in operations.

Discussion/Q and A

Just a comment. Thanks Claire for letting us all know farmers have to adapt to climate change and try to mitigate those risks. These challenges were pointed out by the Norwegians including the steps being taken in finfish and shellfish to try to mitigate issues associated with changing climate. Joel started off by looking at climate factors and noting we are seeing one in one hundred-year storms that are happening more frequently. When they anticipated development of the mining industry Long Harbour in Newfoundland and Labrador, they had Department of Fisheries and Oceans oceanographers try to do predictions around how big the waves could get. Now it is not a 1 in 100 chance more like a 95% change. One important thing I heard today was that farmers have to adapt to climate change and they are using smart technology, temperature sensors, etc. to connect to climate information. Artificial Intelligence (AI) can be used as a tool to help farmers mitigate the risks and hopefully to help address the animal welfare issue as well as the human and infrastructure issues. Claire has shown us that is part of the future and some of the salmon farmers are doing this as well

Joel commented that, in the case of AI, which uses machine-learning technologies to try to make sense of huge amounts of data (something they are doing in a lot of forecasting), one of the biggest issues with any kind of AI as it can't think beyond what has already been seen. It is hard to use AI to extrapolate to new environments. AI systems will fail catastrophically if we put too much faith in them. They are useful to help us see how we got here, but there is a good chance that they predict future risk badly. Extrapolation is not one of the AI skillsets.

Claire thinks what would be good for aquaculture is to get more of a baseline – a kind of dummy's guide. They asked someone in Ottawa, what is the number for rainfall; what is the risk? They couldn't give us the number. Part of the problem is that it changes from farm to farm and even within one farm. So,

obtaining some kind of baseline so we can measure effects is critical at the moment; everything is a guess.

One of the problems is that Environment Canada does its modelling based on a few rainfall gauges. They can assess across a large area but farms need to have their own environmental monitoring capacity.

It was also pointed out that in Canada we don't have farm insurance for aquaculture. For that cost of $70 million from Fiona for aquaculture in Prince Edward Island, there was no farm insurance to help address the burden. That insurance is needed to make the industry more sustainable and to support farmers and growers.

Joel pointed out that one of the ways we have manufactured risk is by moving away from direct monitoring. We are now using remote sensing, etc. and that means we do a lot less direct monitoring. So, we have shifted to satellites and models and we have lost something as a result. Partnering with operations like Claire's can start to get that back and ultimately all that information will improve what anyone can do with AI.

On the subject of AI, it was pointed out that not everyone may be aware that in a lot of cases they are using temperature and monitoring of fish welfare in situ and doing it in real time. They are continuously uploading this information and using it to provide the farmer with decision supports around whether to raise or lower cages. They are using lasers to zap the lice with real time monitoring. Real time monitoring allows you to improve your algorithms and AI models. They have been doing this on land for 15 to 20 years to help farmers decide when to plant seeds, etc. This is not available for small farms and one of the issues there is data privacy and the cost of technology to do the monitoring. What Claire is saying is she wishes people would share data. In a competitive world, farms don't share data, companies don't, particularly companies that want to sell you equipment.

Trine posted a link in the chat to Industry Collaboration Enables Big Data Analytics – AquaCloud This is an initiative for sharing data in Norway.

It was also pointed out that companies in Newfoundland and Labrador are investing in forecasting options like Windy, etc. and some are buying packages to help them predict weather. The speaker thought these were really robust. They used to have a problem with superchill events. Now the operator can monitor that risk and decide not to send boats out by a particular cage that day because when the fish hear the boats, they will come up to the surface to be fed and this increases the risk they will be susceptible to the superchilled water.

Trine commented that, in Norway, there have been a lot of discussions about keeping digital twins for fish farms. Cermac is trying to do a lot more with sensors and surveillance, etc.

Charlie thanked the presenters, commentators and participants for another excellent Dialogue session and reminded them to join us in April for the fourth and final session.